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ABSTRACT

All schools are required to develop and implement an asbestos management plan (AMP). The key component of this plan is each school's operations and maintenance (O&M) program. This report outlines the importance of such programs. It describes an O&M program as an administrative framework that prescribes specific activities and work procedures to control and respond to activities that may disturb asbestos-containing materials. The program's success is contingent on the commitment of all personnel involved in conscientiously implementing O&M program elements and in conducting O&M activities. For this report, a study was conducted to evaluate the implementation of asbestos O&M programs at 10 sites representing 8 New Jersey schools. Each school's O&M program and program compliance were documented. Furthermore, 10 ongoing O&M activities were documented to determine the impact of the activities on airborne asbestos levels. The study found that, overall, the schools were not completely implementing all the elements of the asbestos O&M program as outlined by the EPA and other guidelines. Elements of the program were not performed or they were not communicated to workers or contractors. The report provides a list of references and two appendixes, which include a sample NJDOH-EHS site evaluation/assessment documentation form and a tabular compilation of individual estimates of airborne asbestos concentrations measured before and during O&M activities. (Contains 12 figures and 11 tables.) (RJM)

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Evaluation of the Implementation of Operations and Maintenance Programs in New Jersey Schools

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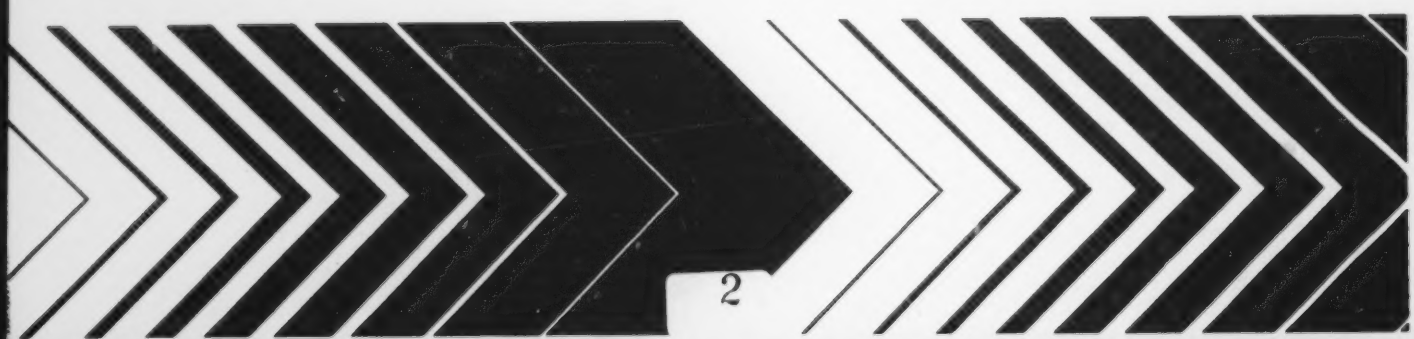

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EVALUATION OF THE IMPLEMENTATION OF OPERATIONS AND MAINTENANCE PROGRAMS IN NEW JERSEY SCHOOLS

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatiable balance between human activities and the ability of natural systems to support and nuture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how polluntants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technilogical and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on the methods for the prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

The Asbestos Hazard Emergency Response Act (AHERA) requires all schools to develop and implement an Asbestos Management Plan (AMP). The U.S. Environmental Protection Agency (EPA) has also published guidance regarding the in-place management of asbestos-containing materials (ACM). The key component of the AMP is the operations and maintenance (O&M) program. An O&M program is an administrative framework that prescribes specific activities and work procedures to control activities that may disturb ACM and respond to any uncontrolled release of asbestos fibers. A well-developed O&M program is ineffective unless it is implemented properly. The O&M program's success is contingent upon the commitment of all personnel involved in conscientiously implementing O&M program elements and conducting O&M activities.

A study was conducted to evaluate the implementation of asbestos O&M programs at 10 sites representing 8 New Jersey schools. The evaluation included aspects required by AHERA as well as those recommended in EPA guidance. Each school's O&M program and compliance with their program during past O&M activities were documented. In addition, 10 ongoing O&M activities were documented to determine the impact of the activities on airborne asbestos levels and to determine compliance with the O&M program during these activities. Airborne asbestos levels were measured by using transmission electron microscopy (TEM) before and during each activity. Personal breathing zone exposures to total fibers were measured by using phase contrast microscopy (PCM) during each activity for comparison with the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.1 f/cm^3, 8-hour time-weighted average.

Overall, the schools were not completely implementing all the elements of the asbestos O&M program as outlined in AHERA or in EPA guidance. Schools performed more O&M program elements required by AHERA than those recommended in EPA guidance. The percentage of performance responses given by the schools indicating that the elements of the O&M program were performed (52.5%) was higher than those provided by the worker or contractor performing the activity (35% and 22.5%, respectively). Elements of the O&M program were not performed or they were not communicated to the worker or contractor. Significant increases in area airborne asbestos levels (determined by TEM) were observed during 5 of the 10 activities. None of the total fiber levels measured using PCM, however, exceeded the OSHA PEL. This study underscores the importance of a thorough O&M program and the effective communication and implementation of all program elements.

Environmental Quality Management, Inc., and the New Jersey Department of Health submitted this document to the U.S. Environmental Protection Agency's Office of Research and Development, National Risk Management Research Laboratory, in partial fulfillment of Contract No. 68-D2-0058 and Cooperative Agreement No. CR-821955-01, respectively. The report covers the period of April 30, 1995 through November 27, 1995 and work was completed as of November 27, 1995.

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This document was written by John R. Kominsky and Ronald W. Freyberg of Environmental Quality Management, Inc., and Donald R. Gerber and Gary J. Centifonti of the Environmental Health Services, New Jersey Department of Health.

SECTION 1

INTRODUCTION

Background

The concern about asbestos-containing materials (ACM) in buildings started in the late 1970s in the United States. In 1978 the U.S. Environmental Protection Agency (EPA) issued a two-volume guidance document to schools for identification and evaluation of in-place asbestos.[1] Subsequently, three additional guidance documents were issued by the EPA in 1983, 1985, and 1990.[2,3,4]

Although removal was encouraged over alternative approaches of asbestos management in the past, in-place management and operations and maintenance (O&M) programs are currently viewed by the EPA as the most appropriate overall strategy for management of asbestos in buildings.[4] In-place management involves the use of building O&M work practices and control measures that minimize the release of airborne fibers from ACM, thereby reducing exposures and associated risks to workers and other building occupants.

Operations and maintenance programs must be prepared and implemented whenever friable ACM is present or assumed to be present in school buildings.[5] An O&M program is a program of work practices and training to maintain friable ACM in good condition, ensure cleanup of asbestos fibers previously released, and prevent future release by minimizing and controlling friable ACM disturbance during installation, repair, maintenance, and cleaning activities. A well-developed O&M program is ineffective unless it is implemented properly. The O&M program's success is contingent upon the commitment of all personnel involved in developing, conscientiously implementing, and conducting O&M activities.

Although these O&M programs have been prepared for schools, no representative field studies have been conducted to evaluate the implementation and effectiveness of these programs in controlling the release of asbestos fibers into a building. The purpose of this study was to evaluate the implementation of O&M programs in selected schools in New Jersey.

Objectives

The objectives of this study were as follows:

1) Document and assess each school's O&M program and other related components in the Asbestos Management Plan.

2) Document and assess each school's compliance with their O&M program during previously conducted O&M activities.

3) Observe and document the conduct of selected O&M activities involving ACM or in the vicinity of ACM.

4) Determine the impact of selected O&M activities on airborne asbestos levels.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following are the principal conclusions reached during this study:

1. Overall, schools were not completely implementing all the elements of the O&M program within the Asbestos Management Plan as outlined in AHERA or in EPA guidance documents. The O&M programs ranged in overall comprehensiveness from 45.9 percent to 83.8 percent with an average of 70.6 percent.

2. School Designated Persons may not be aware of all program elements in the Asbestos Management Plan. The overall percentage of performance responses given by the school officials during the observed O&M activities was 52.5 percent. The school maintenance worker indicated a performance response of only 35 percent, while the outside contractor indicated an even lower performance of 22.5 percent. All elements were not implemented and/or communicated by the school's designated person. Additionally, all program elements were not performed by the workers/contractors conducting the O&M activity.

3. Schools implemented more required items in accordance with AHERA than those additional program elements outlined in EPA guidance documents. The percentage of performance responses was highest in the management elements of AHERA and EPA guidance. The elements indicating implementation items such as notification to workers/ contractors, work permit system, and work practices for the O&M activities had the least percentage of performance responses.

4. O&M activities were performed in the vicinity of ACM without causing elevated airborne asbestos levels. When O&M activities disturbed or were conducted on ACM, however, airborne asbestos levels were significantly elevated and exceeded 0.02 asbestos structure/cm^3 (School Sites A, C, and H).

5. The estimated 8-hour TWA of total fiber concentrations (0.005 f/cm^3 maximum) in the breathing zone of the individual performing the O&M activities (as determined by phase contrast microscopy) did not exceed the OSHA Permissible Exposure Limit of 0.1 f/cm^3, 8-hour TWA.

Recommendations

1. EPA cooperatively with State Agencies need to provide further outreach and education to all responsible parties such as Local Education Agencies, and AHERA Designated Persons as well as the schools' O&M staff, consultants, and contractors to enhance their understanding of the intent and requirements of the O&M aspects of AHERA. Thorough regulatory oversight is necessary to ensure compliance within the requirements of AHERA.

2. A training program for designated persons should be developed that provides an understanding and working knowledge of AHERA, O&M program elements, the Asbestos Management Plan information, and effective implementation of an O&M program.

3. Schools should implement controls to ensure that workers (school employees and outside contractors) who may disturb ACM or perform an activity in the vicinity of ACM are notified as to its location and are aware of the potential for disturbance of ACM. Additionally, each school must enhance programs to ensure that O&M staff receive and are properly trained in handling ACM.

4. Areas of the building that have undergone an O&M activity involving ACM should be thoroughly reinspected for the presence of residual asbestos-containing debris. If asbestos-containing debris is observed, a thorough cleaning and follow-up air monitoring should be conducted.

5. Further research is recommended to evaluate the long-term impact of O&M activities on the release of asbestos structures in the building environment. This information would assist EPA in defining the need for and nature of guidance on asbestos O&M activities.

6. Schools should ensure that workers performing maintenance procedures on asbestos-containing resilient floor tile are informed of the potential for elevated airborne asbestos levels as measured during this and four other EPA studies.

SECTION 3

STUDY DESIGN AND METHODS

Site Selection

The Environmental Health Services - New Jersey Department of Health (EHS-NJDOH) distributed an "O&M Activities Survey Form" to 26 candidate schools representing 14 different school districts that planned to perform O&M activities involving asbestos-containing materials (ACM) or activities in the vicinity of ACM during the summer of 1994. This form solicited information regarding three types of O&M activities: (1) Operations (custodial/service); (2) Maintenance (heating, ventilation, and air-conditioning, plumbing, electrical/communications, fire protection, and other building systems or components); (3) and Renovation (general space modifications, ceiling tile replacement, carpet removal, and roofing repair).

Eight schools, representing 10 distinct O&M activities, were selected based on the type of planned activity and the schedule for conducting the planned activity. The number of schools and activities selected for this study do not represent a statistical sample. The results obtained from the different schools studied were used to document the implementation of the O&M programs at these schools and to identify common factors that may influence airborne asbestos levels during O&M activities on or near ACM.

Evaluation of O&M Programs

A "Site Evaluation/Assessment Documentation Form" was used to standardize the evaluation of each school's O&M Program (Appendix A). To prevent any ambiguity regarding the questions or recording of the responses, the form was administered by

EHS-NJDOH representative who were thoroughly instructed on the basis of each question, as well as its application to the various parts of the evaluation (i.e., Parts 1, 2, and 3 as described below). To ensure data consistency the same persons completed the Site Evaluation/Assessment Documentation Form.

Each school's O&M program evaluation included three primary parts. Part 1 involved a review of each school's O&M program and other related components in the Asbestos Management Plan (AMP) on file with the New Jersey Department of Health (NJDOH) to determine the overall comprehensiveness of the O&M program.* Part 2 involved an on-site interview with the school's AHERA Designated Person to assess each school's compliance with their O&M program during previously conducted O&M activities.** Part 3 involved interviewing the school's AHERA Designated Person and observing and interviewing the worker (school employee or contractor) performing an O&M actual activity.

Part 1 - Each school's Asbestos Management Plan, which was on file with the EHS-NJDOH, was evaluated by an EPA-accredited Inspector/Management Planner prior to initiating the planned activity. The Inspector/Management Planner completed the Site Assessment/Documentation Form during the review of the school's O&M program.

The evaluation included the program elements required by AHERA as well as those elements recommended by EPA in issued guidance.[1-4] Hence, the evaluation was based on three categories of program elements: those program elements required by AHERA; those program elements recommended in EPA guidance documents; and

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* An Asbestos Management Plan is a document that each Local Education Agency (LEA) "School" is required to prepare under the AHERA. It describes all activities planned and undertaken by a school to comply with AHERA regulations, such as building inspections to identify asbestos-containing materials, response actions, and operations and maintenance programs to minimize the risk of exposure to asbestos in school buildings.

** A designated person is the person designated by the LEA to ensure that the AHERA requirements are properly implemented. AHERA established the framework for a regulation which requires, among other things, that elementary and secondary schools identify asbestos-containing materials in school buildings, institute programs aimed at minimizing the risk of asbestos exposure in those buildings, and reinspect those materials at least every three years.

all of the program elements (i.e., those required by AHERA and those recommended in EPA-issued guidance). A "Site Evaluation/Assessment Documentation Form" was used to standardize the evaluation of the respective O&M programs (Appendix A). Each school's O&M Program was evaluated regarding the following elements:

- Comprehensiveness: The program should be developed by a qualified Asbestos Management Planner and implemented by a qualified Asbestos Program Manager/Designated Person following a comprehensive building inspection to identify and assess the condition of all ACM in the building. The written O&M Program should be site-specific and take into account function and building design. The program should address specific activities and procedures related to use, cleaning, maintenance, repairs, equipment service, and fiber release episodes.

- Administration/Awareness: The written Asbestos Management Plan should be available at the school and updated to keep it current with ongoing O&M, periodic surveillance, inspection, reinspection, and response action activities. Additionally, maintenance and custodial personnel must be made aware and have reviewed the Asbestos Management Plan and O&M Program prior to conducting activities.

- Notification: AHERA requires that workers (school employees and contract workers), tenants, and building occupants be notified where ACM is located, and how and why to avoid disturbing the ACM. All persons affected should be properly informed.

- Surveillance: AHERA requires regular 6-month ACM surveillance and 3-year reinspections to note, assess, and document any changes in the condition of the ACM.

- Controls: The program should include a work control/permit system to control activities that might disturb ACM.

- Work Practices: The program should describe O&M work practices to avoid or minimize fiber release during activities affecting ACM.

- Recordkeeping: AHERA requires specific documentation of O&M activities.

- Worker Protection: AHERA requires medical and respiratory protection programs, as applicable.

- Training: AHERA requires proper training of custodial and maintenance staff who may deal with activities involving ACM.

Part 2 - Information regarding previously conducted O&M activities at the school was obtained by interviewing each school's designated person using the "Site Evaluation/Assessment Documentation Form" (Appendix A). This information included the type and location of the O&M activity, the date of the activity, whether key elements of the O&M program were followed, etc. This information was used to assess the school's perception of compliance with their O&M program during previously conducted O&M activities.

Part 3 - Selected O&M activities involving ACM, or in the vicinity of ACM, were observed and documented at each school by using the Site Evaluation/Assessment Documentation Form (Appendix A). The school's AHERA Designated Person was observed and interviewed. In addition, the school employee or contract worker performing the O&M activity was also interviewed regarding use of the elements (e.g., work practices and procedures) specified in the school's O&M program. This information was used to determine the extent of actual compliance with their O&M program during the activity.

Impact of O&M Activities on Airborne Asbestos Levels

The impact of the selected O&M activities on the exposure of custodial workers, maintenance workers, and/or building occupants was evaluated by air monitoring for asbestos structures and total fibers. Characterization of the ACM or source of asbestos structures potentially involved in the O&M activity or near the O&M activity was determined by collecting bulk samples of the material(s).

Air Samples

Five fixed-station area air samples were collected in the immediate area of the O&M activity both before and during the activity. These samples were collected under static conditions (i.e., without intentional disturbance of the air beyond that attributable to general occupant activity or the O&M activity itself). Two field blanks (one open and

one closed) were also collected during each sampling period for each O&M activity as a quality assurance check for filter contamination.

In addition to the fixed-station area air samples, three personal breathing zone samples (i.e., the sampling cassette was placed in the breathing zone of the worker performing the O&M activity) were also collected, when feasible. Two of the three samples were collected for analysis by TEM. The third personal breathing zone sample was collected for analysis by PCM to compare the results to the Occupational Safety and Health Administration (OSHA) PEL of 0.1 f/cm^3, 8-hour time-weighted average. One open field blank was collected as a quality assurance check for each O&M activity for filter contamination.

Bulk Samples

Bulk samples of in-place material were collected to characterize the asbestos content of the ACM (e.g., fireproofing, thermal system insulation, resilient floor tile, plaster) or other sources of asbestos fibers (e.g., debris) potentially involved in the O&M activity.

Sampling Methods

Fixed-Station Area Air Samples

The fixed-station area air samples were collected on open-face, 25-mm-diameter, 0.45-µm poresize, mixed cellulose ester (MCE) filters with a 5-µm poresize MCE diffusing filter and cellulose support pad contained in a three-piece cassette. The labeled filter cassettes were positioned on tripods approximately 5 feet above the floor with the filter face at a 45-degree angle toward the floor. The filter assembly was attached to an electric-powered (110 VAC) 1/6-horsepower vacuum pump operating at a flowrate of approximately 9 liters per minute. At the end of the sampling period, the filters were turned upright before being disconnected from the vacuum pump and then were stored in this position until they were analyzed by the laboratory.

The sampling pumps were calibrated with a precision rotameter (Manostat Model 36-546-215) both before and after sampling. The precision rotameter is a secondary standard; hence, it was calibrated with a primary airflow standard (i.e., a Gilian Gilibrator) both immediately before and after the study.

Personal Breathing Zone Samples

One personal breathing zone air sample was collected on an open-face, 25-mm-diameter, 0.8-µm poresize MCE membrane filter and cellulose support pad contained in a three-piece cassette with a 50-mm conductive extension cowl. This sample was collected in accordance with NIOSH Method 7400 for analysis by PCM for comparison to the OSHA PEL. Two additional personal breathing zone air samples were collected on open-faced, 25-mm-diameter, 0.45-µm poresize MCE filters with a 5-µm poresize MCE diffusing filter and a cellulose support pad contained in a three-piece cassette. These two samples were collected for analysis by TEM.

The three labeled filter cassettes were positioned in the breathing zone of the individual performing the O&M activity. Each filter was attached to approximately 50 feet of Tygon tubing that was attached to an electric-powered (110 VAC) 1/6-horsepower vacuum pump operating at a flowrate of approximately 9 L/min. Traditional battery-powered, personal sampling pumps could not be used because of their limited airflow rates (approximately 2 L/min with the 0.45-µm poresize MCE filter with a 5-µm poresize MCE diffusing filter and a cellulose support pad contained in a three-piece cassette).

The sampling pumps were calibrated with a precision rotameter (Manostat Model 36-546-215) both before and after sampling. The precision rotameter is a secondary standard; hence, it was calibrated with a primary airflow standard (i.e., a Gilian Gilibrator) both immediately before and after the study.

Bulk Samples

The bulk samples of in-place material (e.g., fireproofing, thermal system insulation, plaster, and resilient floor tile) were collected by using a standard coring tool or chipping tool. Other sources of asbestos fibers (e.g., debris) were either collected by

hand or collected using a spatula and brush. All samples were then placed in a labeled sample storage container. The exact location of the sample was recorded on a plan drawing of the building.

Analytical Methods

Area Air Samples

The 0.45-µm poresize MCE filters were prepared and analyzed in accordance with the nonmandatory TEM method specified in the AHERA Final Rule (October 30, 1987; 52 CFR 4826). In addition to the requirements of the AHERA nonmandatory TEM method, the specific length and width of each structure were measured and recorded. A sufficient number of grid openings were analyzed to ensure a sensitivity (the concentration represented by the finding of a single structure) of no greater than 0.005 asbestos structure per cubic centimeter of air sampled, unless the degree of loading made this impractical. On heavily loaded samples, counting stopped after completion of the grid square in which the 100th asbestos structure was found.

Personal Breathing Zone Samples

Each of the 0.8-µm poresize MCE membrane filters used to collect the personal breathing zone samples were analyzed by PCM. These samples were prepared and analyzed according to the NIOSH 7400 protocol (Revision 3, June 5, 1989, National Institute for Occupational Safety and Health Manual of Analytical Methods). All fibers > 5 μm in length and with an aspect ratio of $\geq$ 3:1 were counted using the "A" counting rules. The analytical sensitivity was approximately 0.01 fiber per cubic centimeter of air sampled.

Bulk Samples

The type and percentage of asbestos in bulk samples was determined by polarized light microscopy (PLM) and X-ray diffraction (XRD) in accordance with the "Interim Method for Determination of Asbestos in Bulk Samples" (EPA-600/M4-82-020).

Statistical Methods

Airborne asbestos concentrations measured before and during each O&M activity were characterized for each site by the use of descriptive statistics. The descriptive statistics included the arithmetic mean, minimum and maximum concentrations, and sample size. A one-factor analysis of variance (ANOVA) was used to examine overall differences between baseline concentrations, area air concentrations measured during the O&M activity, and personal breathing zone concentrations measured during the activity. The transformation $\ln(x + 0.002)$, where ln is the natural logarithm and x is the mean airborne asbestos concentration, was applied to each measurement before the ANOVA was performed. The transformation was used to make variances more equal and to provide data that are better approximated by a normal distribution. The constant 0.002, a value chosen to be smaller than the majority of analytical sensitivities, was used because some zero values were present (the natural logarithm of zero is undefined). The transformation was used only for the ANOVA analysis; it was not used for any other part of the data analysis (e.g., plots or descriptive statistics). The data were transferred back to the original scale for reporting purposes. The Tukey multiple comparison procedure was used to distinguish pairwise differences between mean concentrations. All statistical comparisons were conducted at the 0.05 level of significance.

SECTION 4

QUALITY ASSURANCE

Sample Chain of Custody

During the study, sample chain-of-custody procedures were an integral part of both the sampling and analytical activities and were followed for all air and bulk samples collected. The field custody procedures documented each sample from the time of its collection until its receipt by the analytical laboratory. Internal laboratory records then documented the custody of the sample through its final disposition.

Standard sample chain-of-custody procedures were used. Each air and bulk sample was labeled with a unique project identification number, which was recorded on a sample data sheet along with other information (as appropriate), such as sampling date, location of the sample, sampling flow rate, sampling start/stop time, and conditions of sampling.

Sample Analysis

Specific quality assurance procedures outlined in the AHERA rule were used to ensure the precision of the collection and analysis of air samples, including filter lot blanks, open and closed field blanks, and repeated sample analyses.

Filter lot blanks, which are samples selected at random from the lot of filters used in this study, were analyzed to determine background asbestos contamination on the filters. Five percent (100 filters) of the total number of filters (2000 filters) from the lot used in this research study were analyzed by the U.S. EPA, NRMRL TEM laboratory. The filters were prepared by the direct transfer technique and analyzed in accordance with the nonmandatory AHERA TEM method. The TEM analysis of the

100 MCE filters showed a background contamination level of 0 asbestos structure per 10 grid openings on each filter.

Open field blanks are filter cassettes that have been transported to the sampling site, opened for a short time (<30 sec) without air having passed through the filter, and then sent to the laboratory. Closed field blanks are filter cassettes that have been transported to the sampling site and sent to the laboratory without being opened. Ten grid openings were examined on each filter.

A total of 19 0.45-µm open field blanks and 18 0.45-µm closed field blanks were collected and analyzed by TEM; no asbestos structures were detected on any of the field blanks. A total of nine 0.8-µm open field blanks were collected and analyzed by PCM; no fibers were observed on any of the nine open field blanks.

The reproducibility and precision of the TEM analyses were determined by an evaluation of repeated analyses of randomly selected samples. Repeated analyses included replicate and duplicate analyses. A replicate analysis of nine samples was performed to assess the uniformity of the distribution of asbestos structures on a single grid preparation. A replicate analysis is a second analysis of the same grid performed by the same microscopist as did the original analysis. The microscopist uses the same grid preparation but counts different grid openings from those originally read. The results of the replicate analyses are shown in Table 1.

A duplicate sample analysis of four samples was performed to assess the reproducibility of the TEM analysis and to quantify any analytical variability resulting from the filter preparation procedure. A duplicate analysis is the analysis of a second TEM grid prepared from a different area of the sample filter but analyzed by the same microscopist who performed the original analysis. The results of the duplicate analyses are shown in Table 2.

The coefficient of variation (CV) for the replicate and duplicate analyses was estimated by assuming a lognormal distribution for the data on the original scale and estimating the variance on the log scale. The variance was estimated by the mean square error obtained from a one-way ANOVA of the log-transformed data with the sample identification number as the main factor. The CVs associated with the replicate

and duplicate analyses were 20 and 28 percent, respectively. These CVs are consistent with the range of CVs observed in past EPA asbestos research studies.

TABLE 1. DATA SUMMARY FOR REPLICATE ANALYSES[a]

Sample number	Original analysis		Replicate analysis	
	N[b]	s/cm^3	N[b]	s/cm^3
A-01-D1-P-02	107	3.579	115	3.846
D-01-D1-P-01	1	0.004	1	0.004
E-01-B-05	0	<0.005	1	0.004
F-01-B-02	0	<0.004	0	<0.004
F-02-B-04	0	<0.005	0	<0.005
G-01-B-01	0	<0.004	1	0.004
G-02-B-01	0	<0.004	0	<0.004
H-01-B-05	0	<0.004	0	<0.004
H-01-F1-05	0	<0.004	0	<0.004

[a] A second analysis of the same grid performed by the same microscopist as the original analysis.
[b] Number of asbestos structures.

TABLE 2. DATA SUMMARY FOR DUPLICATE ANALYSES[a]

Sample number	Original analysis		Duplicate analysis	
	N[b]	s/cm^3	N[b]	s/cm^3
D-01-D1-01	0	<0.004	0	<0.004
F-02-D1-P-02	2	0.010	1	0.005
G-02-D1-01	2	0.008	3	0.012
H-01-F1-04	0	<0.004	0	<0.004

[a] A second TEM grid preparation was analyzed by the same microscopist.
[b] Number of asbestos structures.

SECTION 5

RESULTS AND DISCUSSION

Site Descriptions

Eight schools representing seven school districts were surveyed during this study. All eight of these schools have participated in past asbestos-related studies conducted cooperatively by EPA and EHS-NJDOH. A total of 10 O&M activities were evaluated at these 8 schools; 2 activities were evaluated at 2 of the schools (Sites F and G) and 1 activity was evaluated at each of the other 6 schools. A summary matrix of each study site and the O&M activity evaluated is presented in Table 3.

Assessment of O&M Programs

The evaluation of the data for each school's O&M program was grouped into three categories: *AHERA Elements*, including those program elements required by AHERA; *Guidance Elements*, including those program elements recommended in EPA-issued guidance; and *All Elements*, including all of the program elements (i.e., the first two categories combined). Each school's O&M program evaluation was also divided into three primary parts: *Part 1* (AMP) which included the information contained in the school's AHERA AMP filed with the EHS-NJDOH; *Part 2* (previous O&M activities), which included the previously conducted O&M activities information obtained by interviewing each school's AHERA Designated Person; and *Part 3* (observed O&M activities), which included the information obtained by direct observation of O&M activities.

TABLE 3. CHARACTERISTICS OF STUDY SITES AND O&M ACTIVITIES EVALUATED

Site	O&M Category	Work Performed By	Description of O&M Activity and ACM
A	Operations	Employee[a]	Wet-stripping 2000 ft^2 of floor tile (10-20% chrysotile, good condition); 300 rpm machine with black pad.
B	Maintenance	Employee	HEPA-vacuuming interior of boiler; boiler sealant/rope/gasket (10-85% chrysotile, good condition) material.
C	Renovation	Contractor	Space modification (demolition of plaster walls & ceilings); pipe insulation (25-35% chrysotile) in area was severely damaged during the demolition.
D	Maintenance	Employee	HEPA-vacuuming of HVAC unit's in classrooms; ACM in area was floor tile (1-3% chrysotile, good condition).
E	Renovation	Contractor	Removal of 1500 ft^2 of carpet on floor tile (10% chrysotile); insulation on piping (10% chrysotile, good condition) above ceiling.
F_1	Maintenance	Employee	Changing of air filters and vacuuming of interior of air handling unit in mechanical room; insulation on piping (2% chrysotile, fair condition) above ceiling. Floor tile (5% chrysotile, good condition).
F_2	Maintenance	Contractor	Pulled wiring above suspended ceiling tile for installation of smoke detectors; insulation on pipes (20% chrysotile, good condition) above ceiling panels. Floor tile (5% chrysotile, good condition).
G_1	Renovation	Employee	Removal/replacement 2-ft x 4-ft ceiling panels; insulation on pipes (>1% chrysotile, good condition) and transite panels (50-55% chrysotile, fair condition) above ceiling panels, floor tile (10-15% chrysotile, good condition).

(continued)

TABLE 3 (continued)

Site	O&M Category	Work Performed By	Description of O&M Activity and ACM
G_2	Maintenance	Contractor	Pulled Romex electrical conductor cable above suspended ceiling; insulation on pipes (>1% chrysotile, good condition) and transite panels (50-55% chrysotile, fair condition) above ceiling panels, floor tile (10-15% chrysotile, good condition).
H	Maintenance	Contractor	Drilled holes into acoustical plaster (5% chrysotile, good condition) to install smoke and heat detectors.

[a] Denotes that the work was performed by an employee of the school.

Comparisons By Category

Table 4 and Figures 1 through 3 summarize the individual performance responses for each site by part and category. Figure 4 presents the average percentage of performance response for all sites by part and category. The responses to questions on the Site Assessment/Documentation Form are termed "performance responses" in this report. A "yes" indicates an affirmative response to the respective question, as well as indicates that the particular activity or function had been accomplished. For example, a "yes" response to Question C.1 "Surveillance" would indicate that the 6-month periodic surveillance had been conducted.

AHERA Elements - Overall, the performance responses were highest for elements required by AHERA. The AMP performance responses ranged from 69.6 to 95.7 percent with an average of 88.3 percent. At 7 of 10 sites, the AMP indicated greater than 90 percent performance response. Only one site's AMP had less than 70 percent performance response. It should be noted that for the evaluation of the information required by AHERA in the AMP, it is possible to have less than 100 percent performance for the purpose of this study. Some O&M program elements could not be verified because they would not be performed until a future date, i.e., a date beyond the time when the AMP was reviewed by the EHS-NJDOH inspector. In previous O&M activities, performance responses in 8 of 10 sites were less than noted in the AMP. In the observed O&M activities, performance responses in all sites were less than those documented in the AMP and averaged 58.9 percent.

Guidance Elements - Overall, in all three parts, the performance responses noted in this category were the lowest. The AMP performance responses ranged from 7.1 to 71.4 percent with an average of 41.4 percent. At 8 of 10 sites, the AMP indicated less than 70 percent performance response. The lower responses could be attributed to some of the guidance information (particularly the "Green Book"[4]) not being available when the AMPs were prepared in 1987 to 1989. The performance responses averaged only slightly higher in previous O&M activities (54.1 percent) and during the observed O&M activities (44.0 percent). Although all of the guidance was

TABLE 4. PERCENTAGE OF PERFORMANCE RESPONSES FOR PROGRAM ELEMENTS

Study Site	Required by AHERA			EPA Guidance			All Elements[d]		
	Part 1[a]	Part 2[b]	Part 3[c]	Part 1	Part 2	Part 3	Part 1	Part 2	Part 3
A	95.7	58.3	66.7	50.0	47.1	46.7	78.4	53.7	54.2
B	91.3	50.0	22.2	35.7	41.2	6.7	70.3	46.3	12.5
C	78.3	95.8	77.8	50.0	100	80.0	67.6	97.6	83.3
D	91.3	54.2	77.8	71.4	23.5	20.0	83.8	41.5	33.3
E	69.6	95.8	66.7	7.1	76.5	66.7	45.9	87.8	66.7
F_1	95.7	12.5	44.4	14.3	23.5	13.3	64.9	12.5	25.0
F_2	95.7	16.7	44.4	14.3	23.5	13.3	64.9	19.5	25.0
G_1	91.3	75.0	55.6	50.0	88.2	80.0	75.7	80.5	70.8
G_2	91.3	75.0	55.6	50.0	88.2	73.3	75.7	80.5	66.7
H	82.6	66.7	77.8	71.4	29.4	40.0	78.4	51.2	54.2
Average	88.3	60.0	58.9	41.4	54.1	44.0	70.6	57.6	49.2

[a] Part 1 involved a review of each school's Asbestos Management Plan.

[b] Part 2 involved an interview with the school's AHERA Designated Person regarding previous O&M activities.

[c] Part 3 involved information from the school's AHERA Designated Person and the individual performing the observed O&M activity.

[d] Includes the O&M program elements required by AHERA and those recommended in EPA-issued guidance.

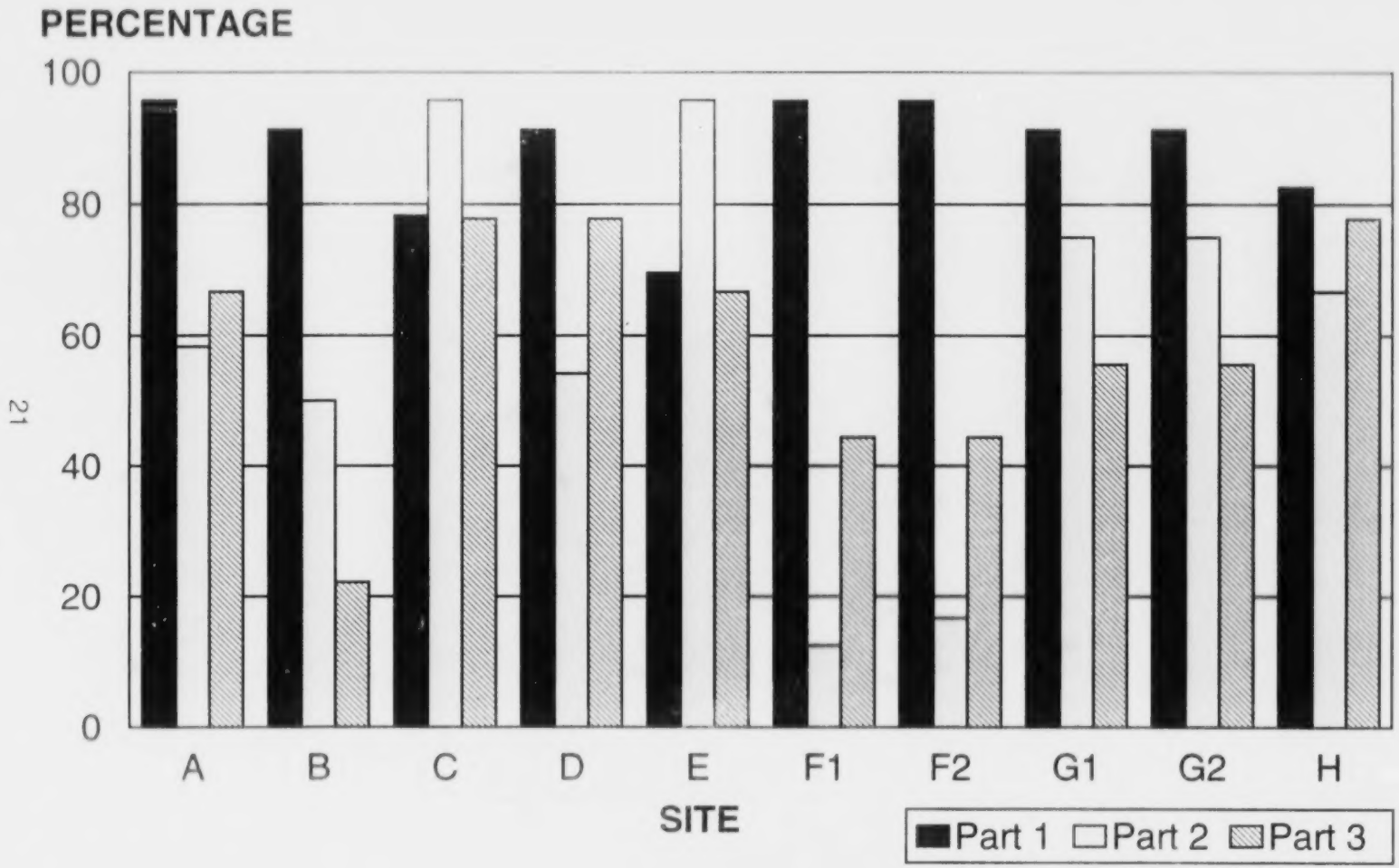

Figure 1. Percent total performance of program elements required by AHERA.

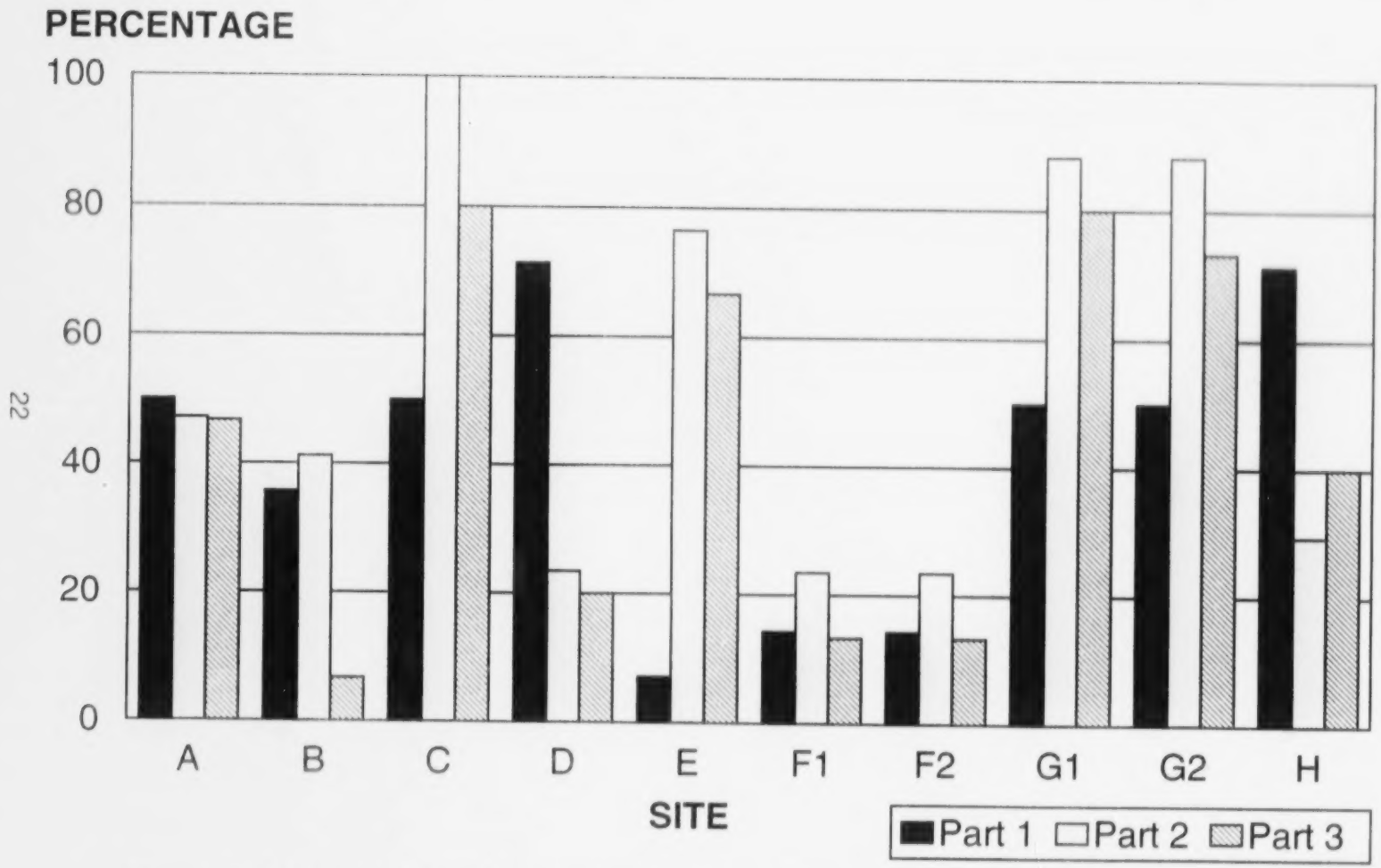

Figure 2. Percent total performance of program elements recommended in EPA Guidance.

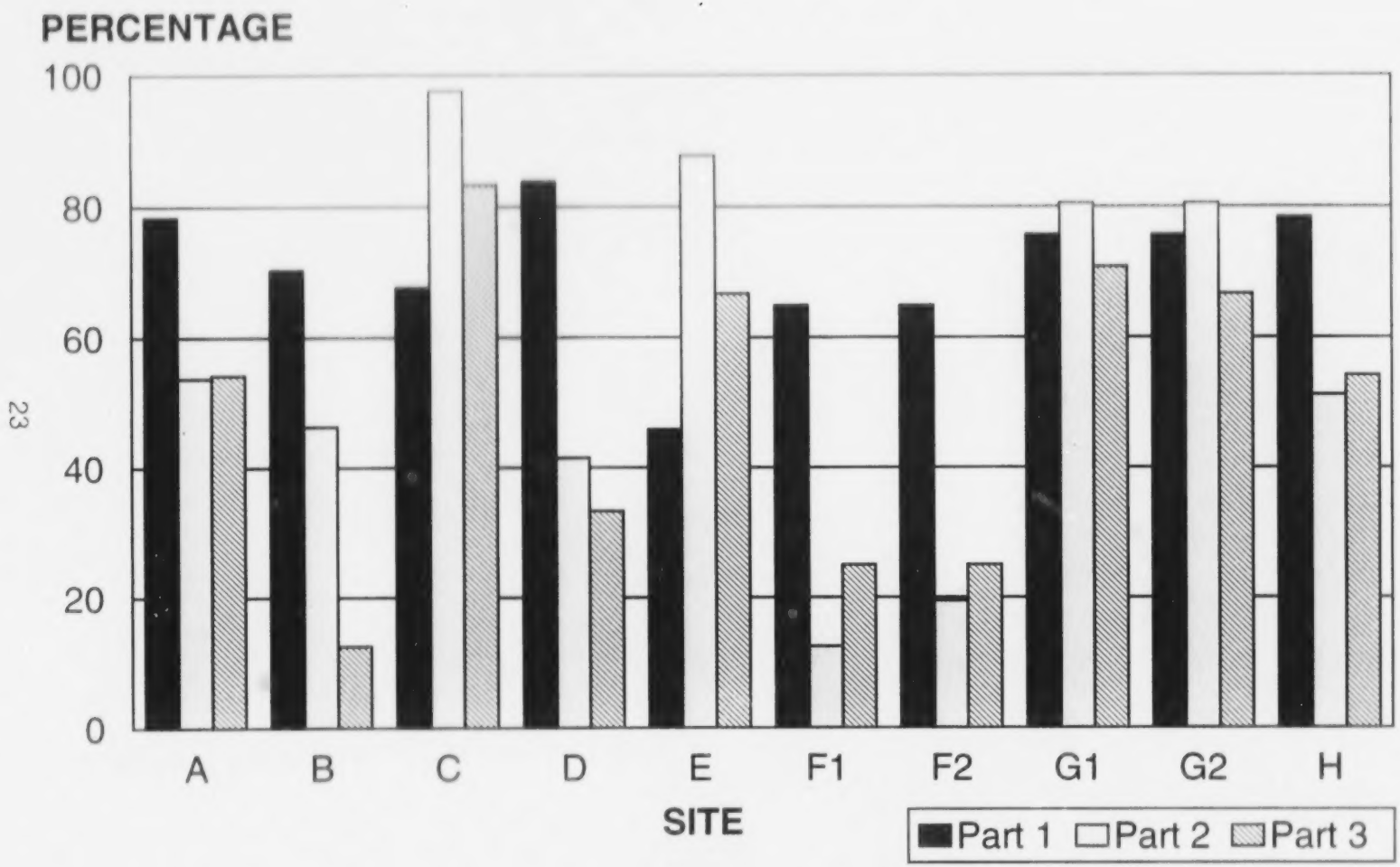

Figure 3. Percent total performance of all program elements.

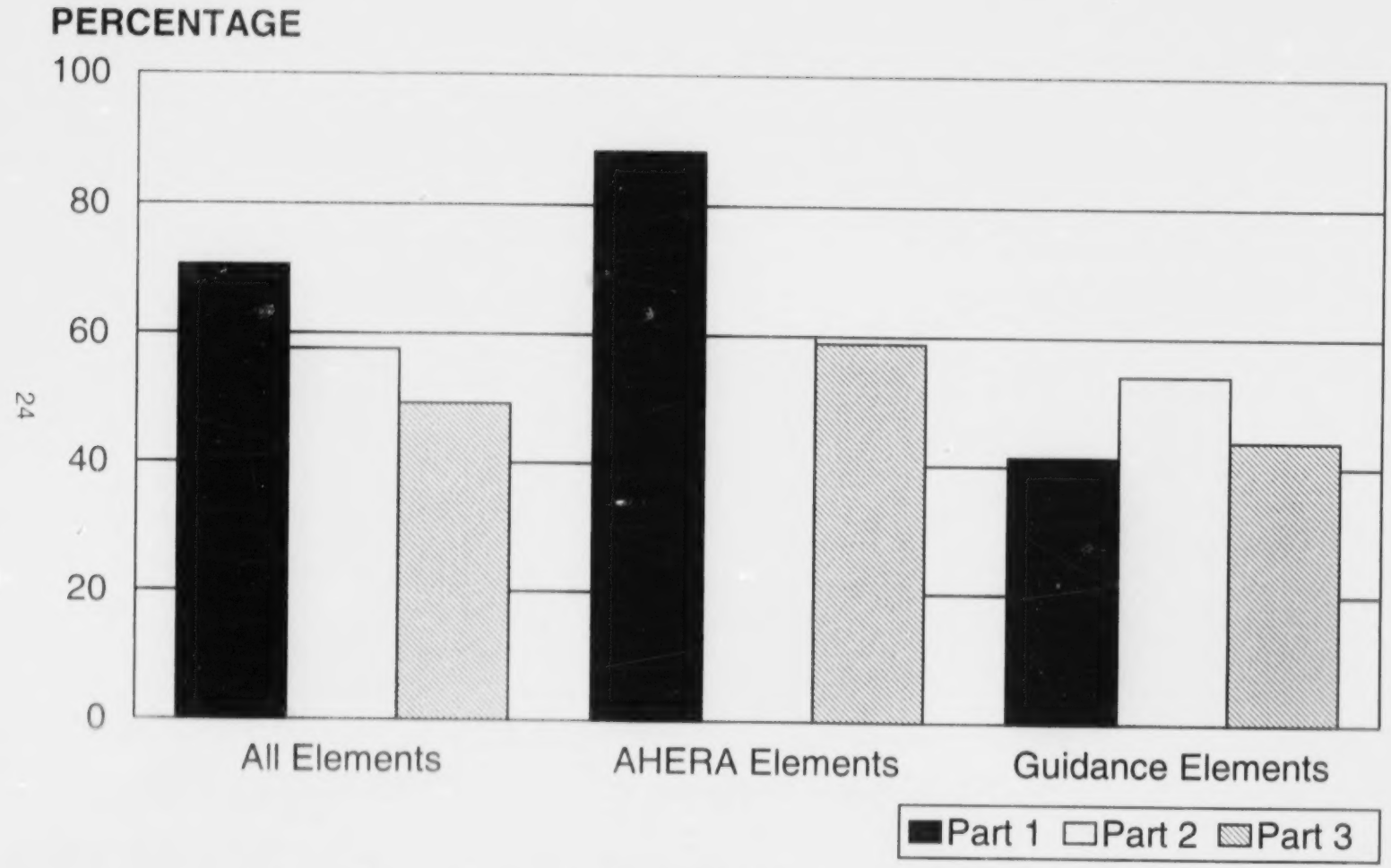

Figure 4. Average percentage of performance response for all sites by category and parts for the O&M program elements.

available for approximately five years prior to this evaluation, the most recent EPA guidance (the "Green Book") is not geared specifically toward schools, but for buildings in general. Hence, the schools may not be aware of the guidance or may choose not to implement the guidance recommendations since it's not a regulatory requirement.

All Elements - A comparison of the data contained in the AMP, with the performance responses from previous O&M activities and a comparison with the observed O&M activities suggest a trend in decreasing percentage of performance responses. The AMP documented an average performance response of 70.6 percent, whereas the school stated that it performed 57.6 percent of the O&M elements during previous O&M activities, and performed 49.2 percent of the elements during the observed O&M activity. In the observed O&M activities, performance responses in 8 of 10 sites were less than those noted in the asbestos management plan.

Comparisons by Part

Table 4 summarizes the individual performance responses for each site by part and category. Figure 5 presents the average percentage of performance response for all sites by part and category.

Part 1 - At all sites, the individual percentage of AHERA element performance responses was higher than those recommended in EPA Guidance elements. The number of sites with performance responses less than 70 percent was only 1 of 10 for AHERA elements and 8 of 10 for Guidance elements. The average performance response for AHERA elements (88.3 percent) was 53.1 percent higher than the average performance response for Guidance elements (41.4 percent).

Part 2 - The average performance response for Guidance elements (54.1 percent) was 9.8 percent lower than the average performance response for AHERA elements (60.0 percent). All three categories had 6 of 10 sites with performance responses less than 70 percent.

Part 3 - The average performance response for Guidance elements (44.0 percent) was 25.3 percent lower than the average performance response for AHERA

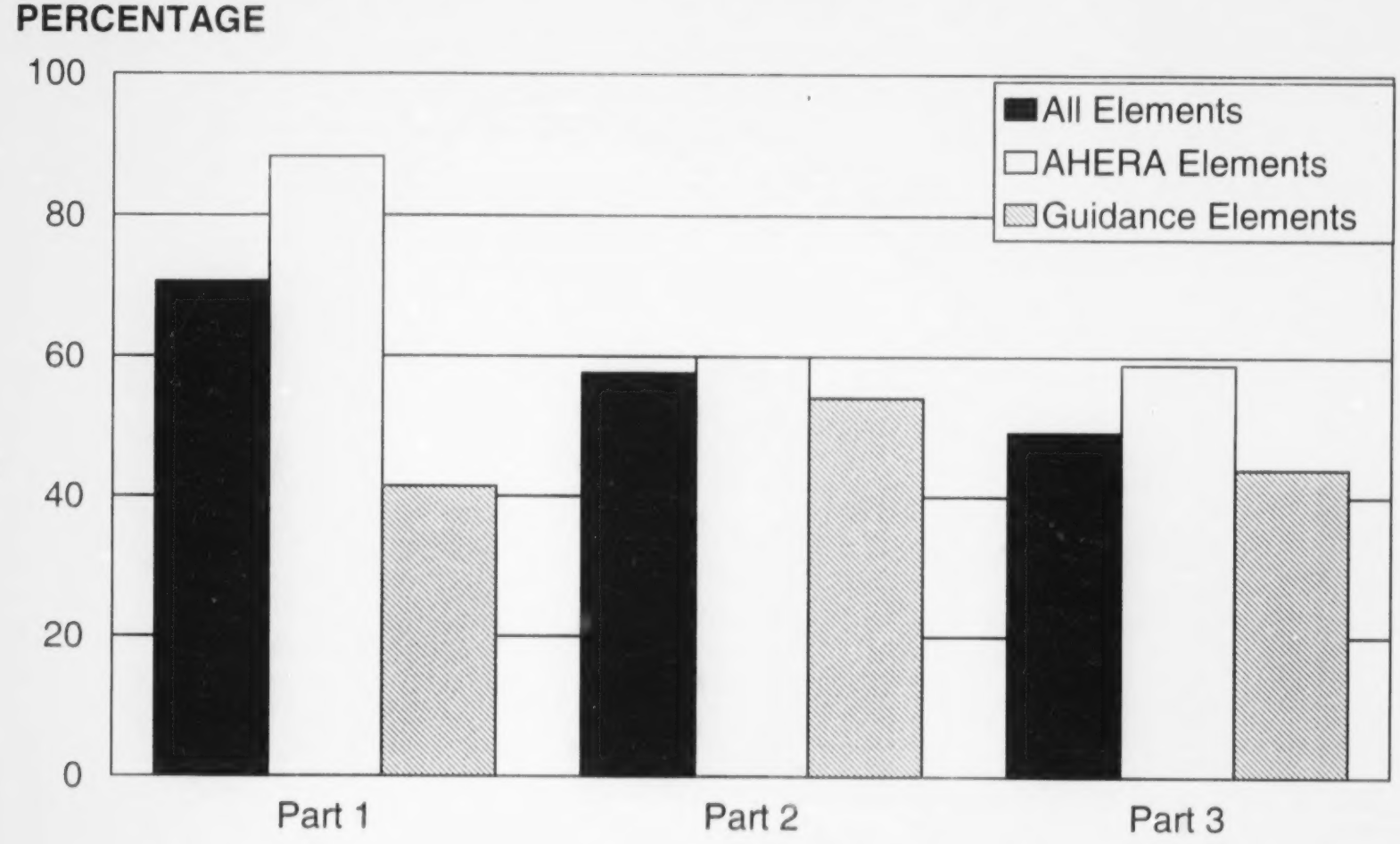

Figure 5. Average percentage of performance responses for all sites by parts and category for the O&M program elements.

elements (60.0 percent). All three categories had 6 of 10 sites with performance responses less than 70 percent.

Part 3 - The average performance response for Guidance elements (44.0 percent) was 25.3 percent lower than the average performance response for AHERA elements (58.9 percent). Both the AHERA elements and Guidance elements categories had 7 of 10 sites with performance responses less than 70 percent.

Comparisons of School, Worker, and Contractor Performance Responses

Further evaluation was made to compare the performance responses of the school officials to those of the persons actually performing the observed O&M activity. Both the school Designated Person and the school maintenance worker or the outside contractor performing the activity where asked specific questions regarding the observed O&M activities. Table 5 summarizes the responses for these specific questions for the "All Elements" and "AHERA Elements" categories. The performance response for "All Elements" indicated by the school Designated Person was 52.5 percent, whereas the performance response indicated by the school maintenance worker was 35 percent. The outside contractor indicated that 22.5 percent of the O&M elements were performed. Figure 6 shows approximately a 33.3 percent decrease in the performance response from the school Designated Person to the school maintenance worker. Similarly, a 57.1 percent decrease in the performance response from the school Designated Person to the outside contractor was observed. This also reflects a 35.7 percent decrease in performance response from the school maintenance worker to the outside contractor. The performance responses for "AHERA Elements" were very similar as was the trend of decreasing performance responses from the school Designated Person to the school maintenance worker and the outside contractor.

TABLE 5. PERCENTAGE OF PERFORMANCE RESPONSES FOR PART 3 FROM INDIVIDUAL SCHOOL, WORKER, AND CONTRACTOR RESPONSES

Elements	Percentage of Performance Responses		
	School Designated Person	School Worker	Contractor
All Elements	52.5	35.0	22.5
AHERA Elements	60.0	37.5	25.0

Comparisons by Program Elements

Table 6 and Figure 7 present the performance responses to the individual program elements for both the AHERA-required and EPA-recommended elements by Parts 1, 2, and 3. Generally, decreases in performance responses for each element are noted from the elements documented in the AMP (Part 1), to previous O&M activities (Part 2), and to what was actually observed during the O&M activity (Part 3). An overall average was calculated across all sites for each program element. When the AMP is evaluated according to the "All Elements" category, surveillance, recordkeeping, and training had the highest percentage of performance responses. Other program elements scored less, with all being less than 80 percent. Work practices and work permit system program elements scored the lowest, with 57.5 percent and 38.9 percent, respectively.

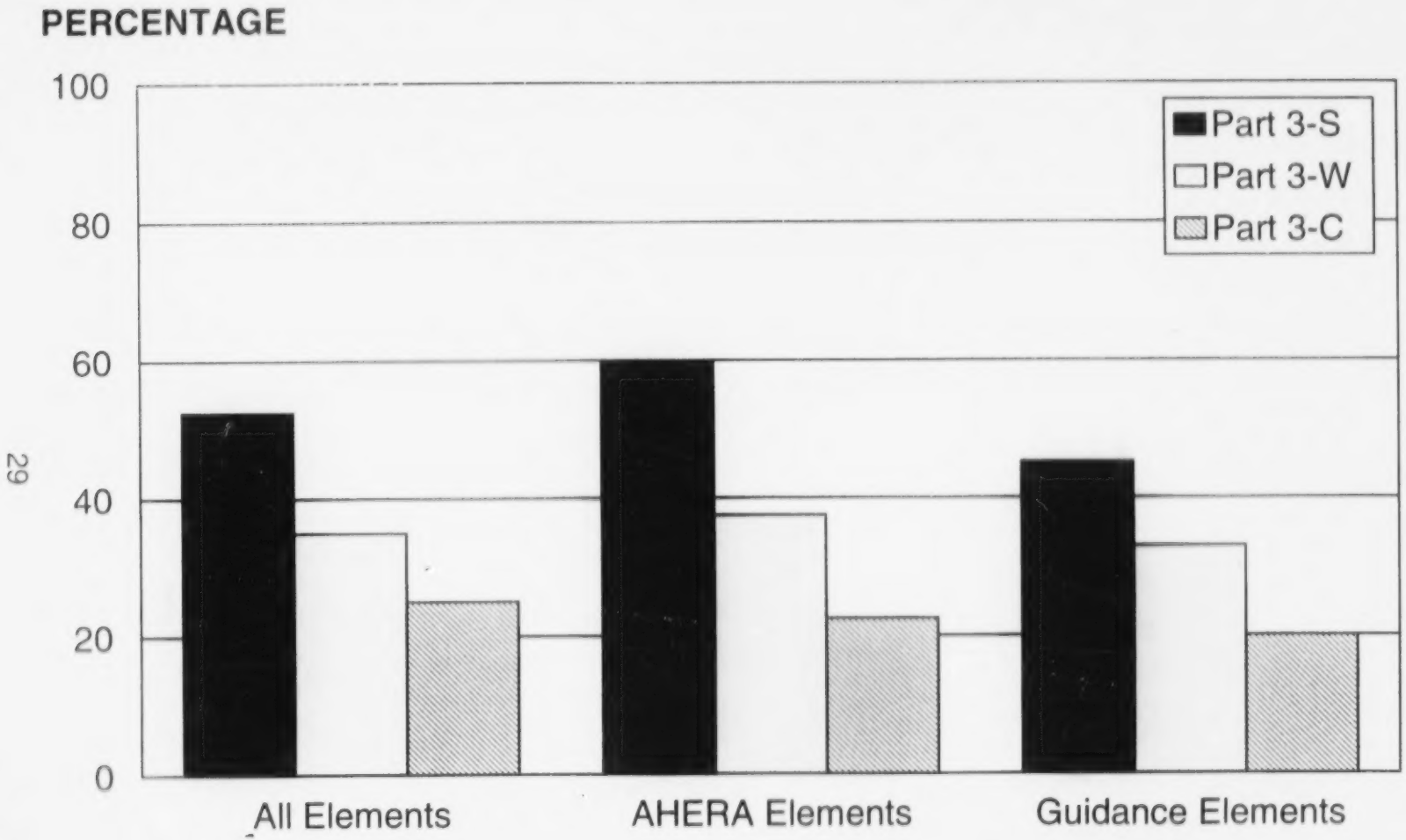

Figure 6. Average percentage of performance responses for all sites by category and Part 3 individual school, worker, and contractor responses to O&M program elements.

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Impact of O&M Activities on Airborne Asbestos Levels

TEM Air Monitoring Results

Table 7 presents the summary statistics for the airborne asbestos concentrations measured before and during each O&M activity at each site. Individual sample results of airborne asbestos concentrations are presented in Appendix B. A one-way ANOVA was used to compare airborne asbestos concentrations measured before each activity to area and personal breathing zone concentrations measured during the activity at each site. Table 8 summarizes the results of these comparisons for each O&M activity. Some O&M activities were performed in the vicinity of ACM without causing elevated airborne asbestos levels. Five of 10 activities (Sites A, C, F_1, F_2, and H) showed significant increases in airborne asbestos concentrations during the associated O&M activity when compared to baseline measurements (Figures 8 - 12). Another study, conducted over a 4 year period, concluded that O&M activities that disturbed ACM (including thermal system insulation and plaster, and resilient floor tile) may have contributed to elevated airborne asbestos levels at several of the sites.[6]

Additionally, when O&M activities disturbed ACM in the vicinity or were conducted on ACM, airborne asbestos levels were elevated at or above 0.02 s/cm^3 in 4 of 10 sites (A, C, F_1, and H). The 0.02 s/cm^3 criterion was derived from the AHERA clearance criterion of 70 s/mm^2 (CFR 763). In schools with mean airborne asbestos concentrations greater or equal to 0.02 s/cm^2 the NJDOH required that a response action to be taken by the school to lower the asbestos levels below 0.02 s/cm^2. An EPA-certified Building Inspector/Management Planner from the EHS-NJDOH performed a visual inspection of the affected areas to assist the school in locating any potential sources of asbestos contamination. These areas were then cleaned by the school and air monitoring was conducted to demonstrate that the airborne asbestos concentrations were below 0.02 s/cm^2. The follow-up air samples were analyzed by EPA.

TABLE 6. AVERAGE PERFORMANCE RESPONSES FOR ALL SITES BY ELEMENT AND PART (ALL ELEMENTS CATEGORY)

Program Elements	Parts		
	1[a]	2[b]	3[c]
Administration	72.3	66.4	68.0
Notification	76.7	30.0	35.0
Surveillance	100	75.0	-
Work Control/Permit System	38.9	45.6	38.9
Work Practices	57.5	44.0	33.3
Recordkeeping	97.5	70.0	75.0
Personal Protective Equipment	70.0	50.0	80.0
Training	90.0	65.0	45.0
Totals	70.6	57.6	49.2

[a] Part 1 involved a review of each school's Asbestos Management Plan.

[b] Part 2 involved an interview with the school's AHERA Designated Person regarding previous O&M activities.

[c] Part 3 involved information from the school's AHERA Designated Person and the individual performing the observed O&M activity.

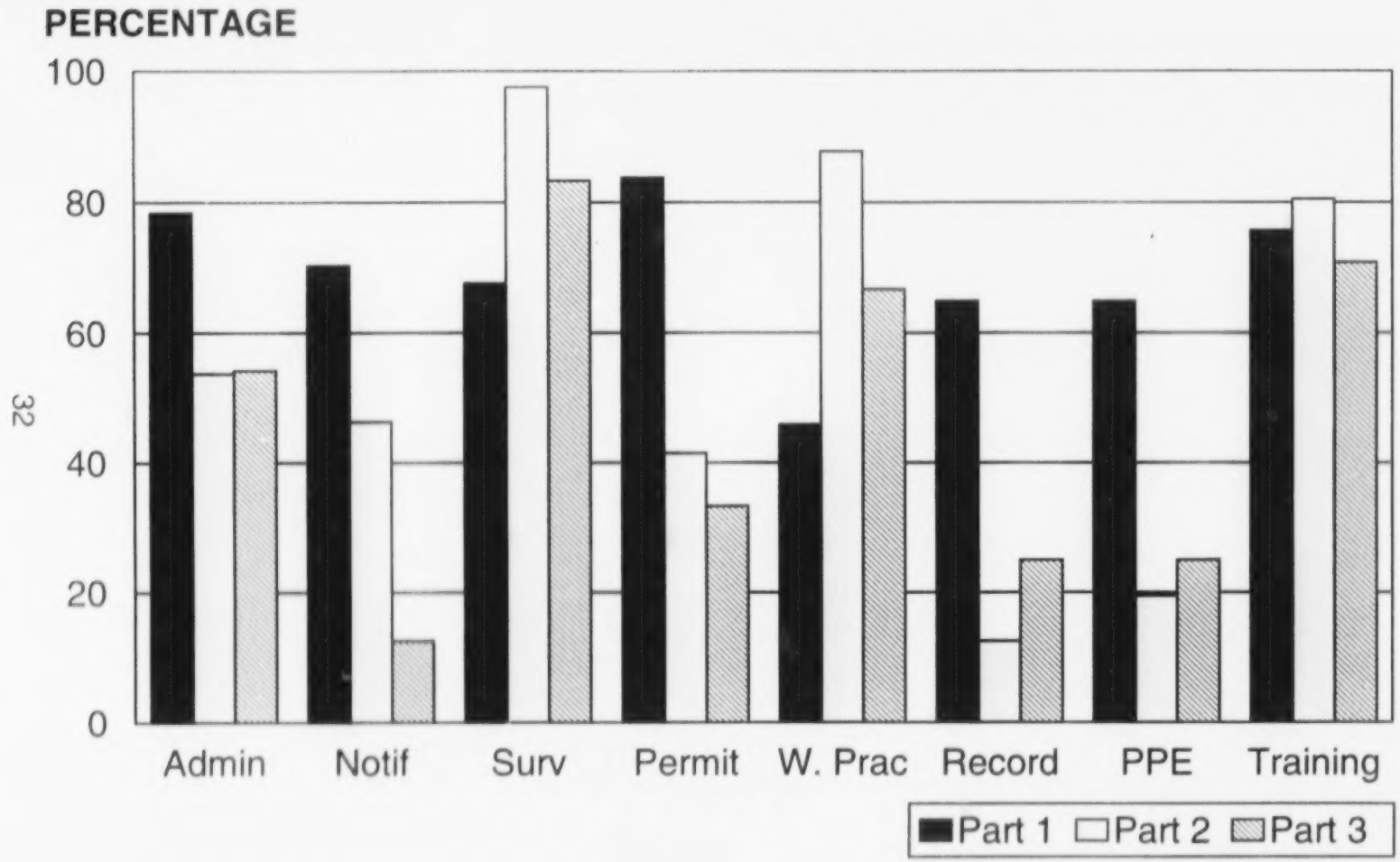

Figure 7. Average percentage of performance response for all sites by element and part for all O&M program elements.

TABLE 7. SUMMARY STATISTICS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED BY TEM BEFORE AND DURING EACH O&M ACTIVITY

Sample Type	N	Airborne Asbestos Concentration, s/cm^3			
		Arithmetic Mean	Geometric Mean	Minimum	Maximum
Site A - Wet-Stripping of Resilient Floor Tile					
Baseline	5	0.003	0.002	<0.004	<0.004
During (Area)	5	3.948	3.91	3.30	4.84
During (Personal)	2	3.305	3.29	3.03	3.58
Site B - Vacuuming Interior of Boilers					
Baseline	5	0.004	0.003	<0.004	0.009
During (Area)	5	0.008	0.006	<0.005	0.021
During (Personal)	1	0.002	0.002	<0.004	<0.004
Site C - Space Modification					
Baseline	5	0.004	0.003	<0.003	0.008
During (Area)	8	0.026	0.020	<0.004	0.050
Site D - Vacuuming Air Handling Unit					
Baseline	5	0.002	0.002	<0.004	0.004
During (Area)	5	0.003	0.003	<0.004	0.004
During (Personal)	3	0.003	0.003	<0.004	0.004
Site E - Carpet Removal					
Baseline	5	0.003	0.001	<0.005	0.005
During (Area)[a]	5	-	-	-	-
Site F_1 - Changing Filters & Vacuuming Air Handling Unit					
Baseline	5	0.005	0.003	<0.004	0.013
During (Area)	5	0.011	0.007	<0.005	0.024
During (Personal)	2	0.042	0.042	0.038	0.046

(continued)

TABLE 7 (continued)

Sample Type	N	Airborne Asbestos Concentration, s/cm^3			
		Arithmetic Mean	Geometric Mean	Minimum	Maximum
Site F_2 - Installation of Smoke Detector Wiring					
Baseline	5	0.002	0.003	<0.004	0.005
During (Area)	5	0.003	0.003	<0.005	<0.005
During (Personal)	2	0.008	0.009	0.005	0.010
Site G_1 - Ceiling Tile Removal\Replacement					
Baseline	5	0.012	0.007	<0.004	0.039
During (Area)	5	0.004	0.004	<0.004	0.008
During (Personal)	2	0.006	0.006	0.004	0.008
Site G_2 - Installation of Flexible Conduit Above Suspended Ceiling					
Baseline	5	0.006	0.004	<0.004	0.013
During (Area)	5	0.011	0.009	<0.004	0.023
During (Personal)	2	0.014	0.008	<0.005	0.026
Site H - Installation of Fire Alarm System					
Baseline	5	0.003	0.003	<0.004	0.004
During (Area)	5	0.056	0.053	0.030	0.076
During (Personal)	2	0.145	0.120	0.064	0.226

[a] Samples collected during the O&M activity at Site E were too heavily loaded to count.

(continued)

TABLE 8. SUMMARY OF ANOVA COMPARISONS

Site - Activity		ANOVA p-value	Tukey pairwise comparisons[a,b,c]
Site A -	Wet-stripping of resilient floor tile	0.0001	B(0.002) DP(3.29) DA(3.91)
Site B -	Vacuuming interior of boilers	0.3627	DP(0.002) B(0.003) DA(0.006)
Site C -	Space modification	0.0102	B(0.003) DA(0.020)
Site D -	Vacuuming air handling unit	0.4889	B(0.002) DA(0.003) DP(0.003)
Site F_1 -	Changing filter and vacuuming air handling unit	0.0254	B(0.003) DA(0.007) DP(0.042)
Site F_2 -	Installation of smoke detector wiring	0.0059	DA(0.003) B(0.003) DP(0.009)
Site G_1 -	Ceiling tile removal replacement	0.5192	DA(0.004) DP(0.006) B(0.007)
Site G_2 -	Installation of flexible electrical conduit above suspended ceiling	0.5650	B(0.004) DA(0.009) DP(0.008)
Site H -	Installation of fire alarm system	0.0001	B(0.003) DA(0.053) DP(0.120)

[a] B = Baseline; DA = Area samples during the activity; DP = Personal samples during the activity.

[b] Parenthetical entries are geometric average airborne asbestos concentrations (s/cm^3).

[c] Geometric average concentrations connected by a line are not significantly different.

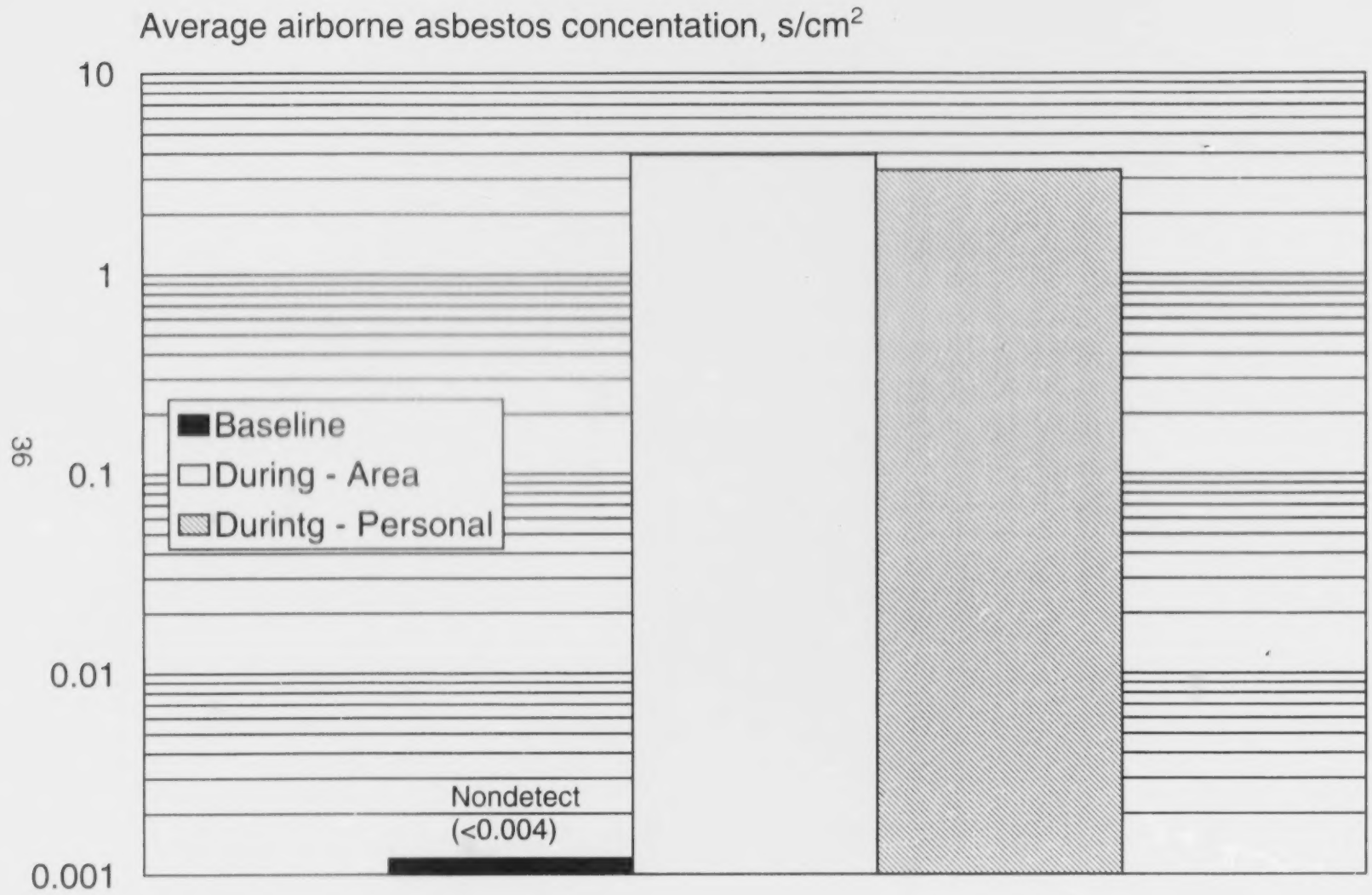

Figure 8. Average airborne asbestos concentrations before and during wet-stripping of resilient floor tile at Site A.

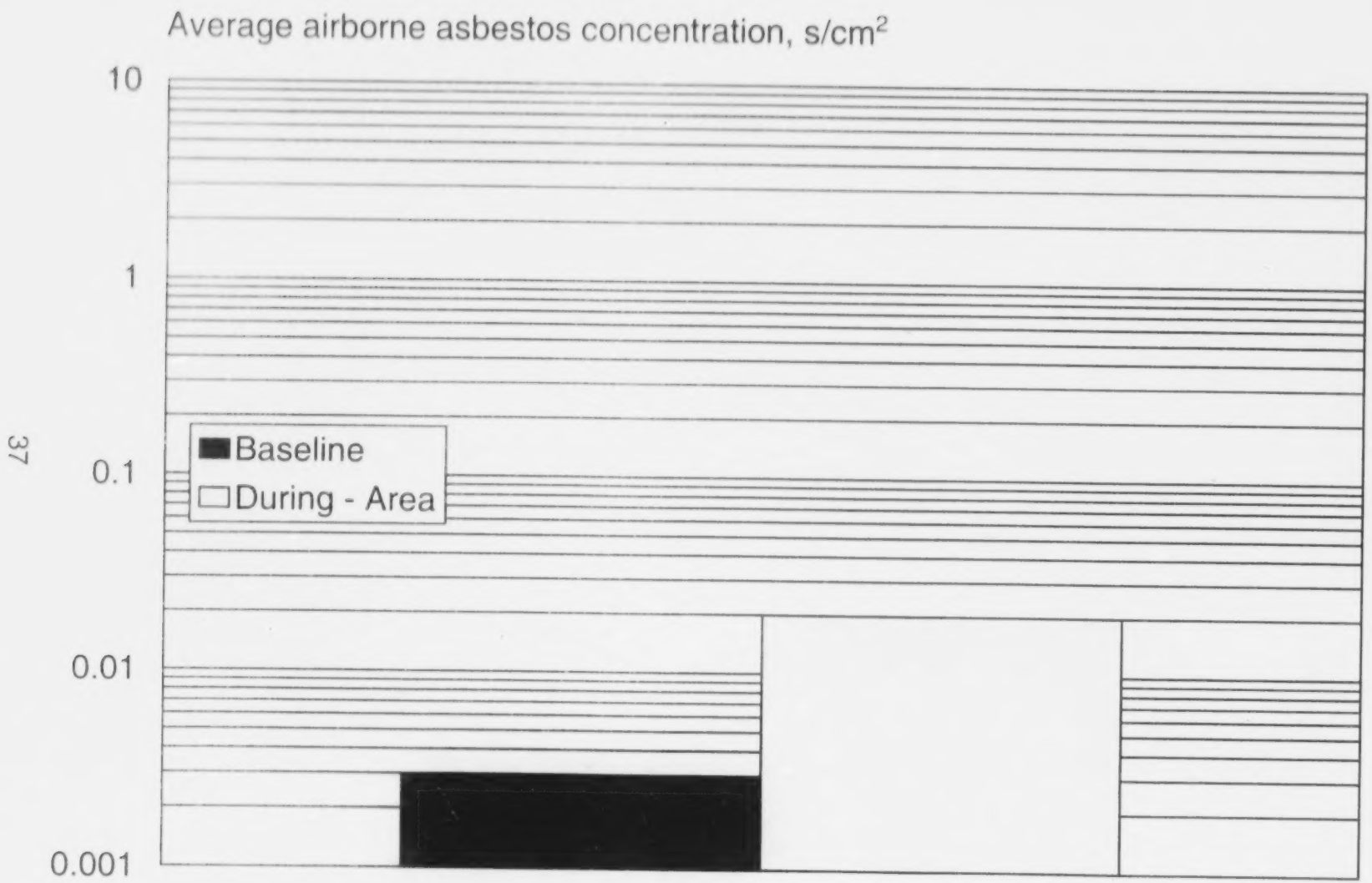

Figure 9. Average airborne asbestos concentrations before and during rennovation at Site C.

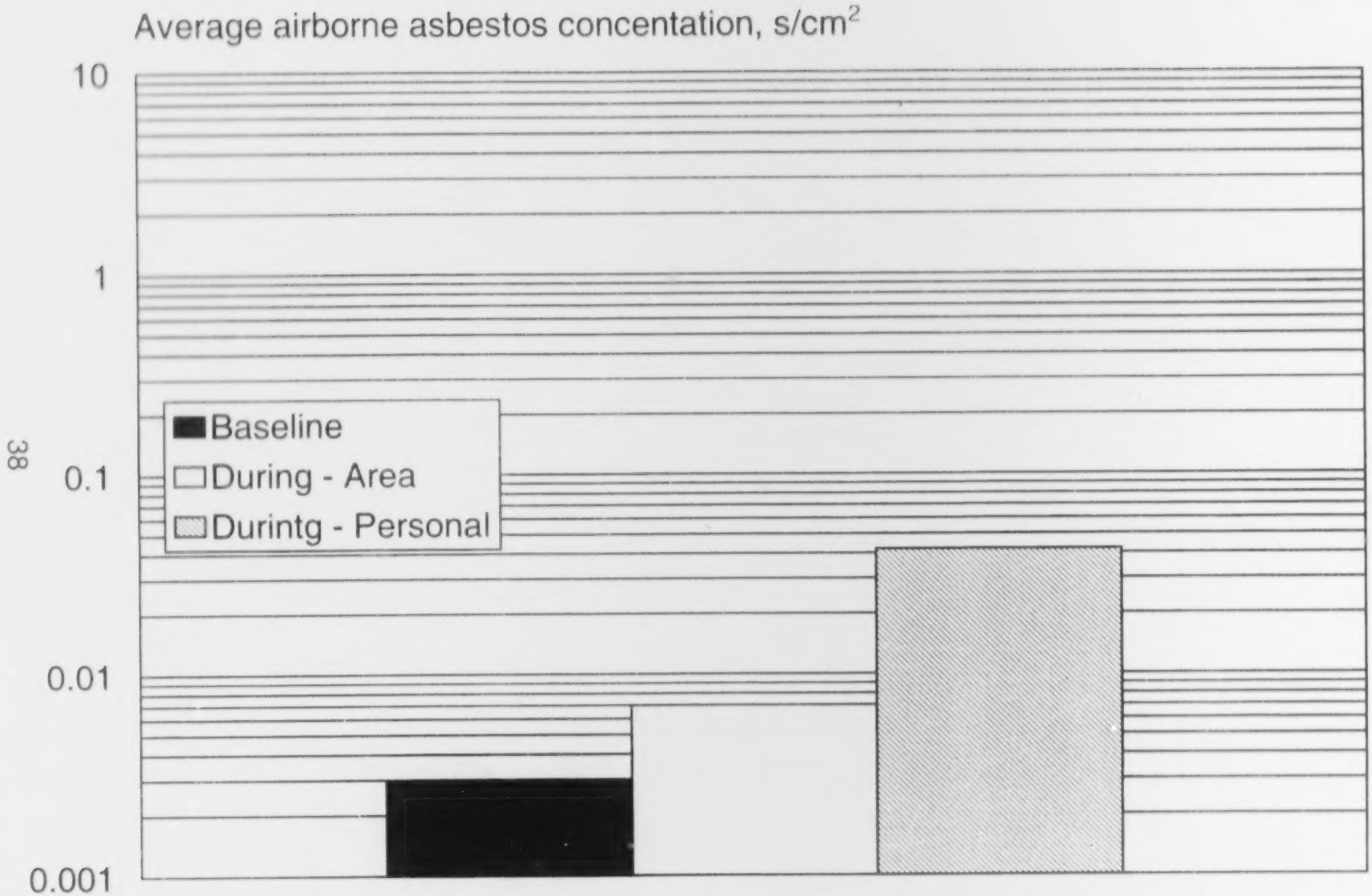

Figure 10. Average airborne asbestos concentrations before and during changing filter and vacuuming air handling unit at Site F_1.

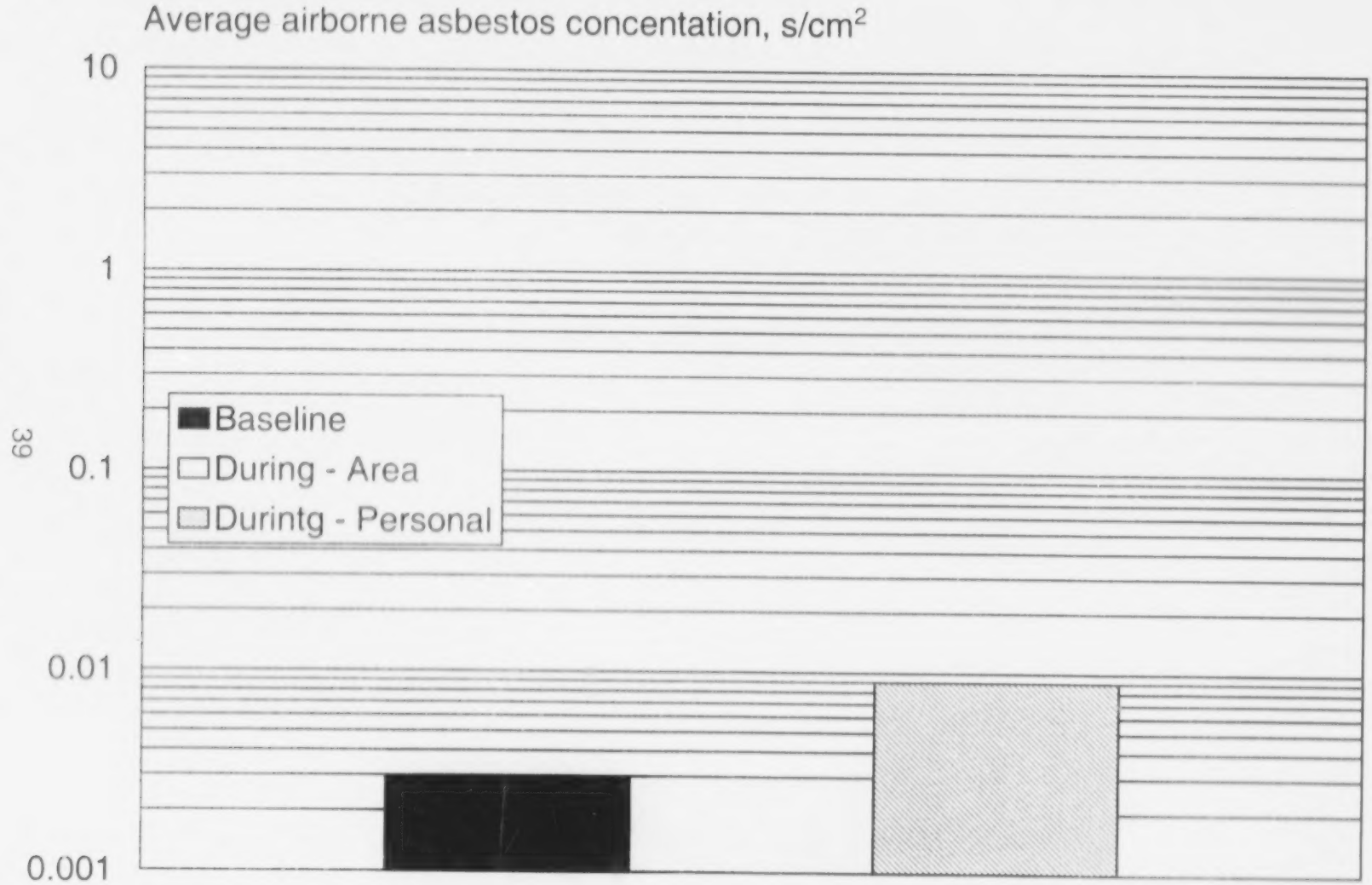

Figure 11. Average airborne asbestos concentrations before and during installation of smoke detector wiring as Site F_2.

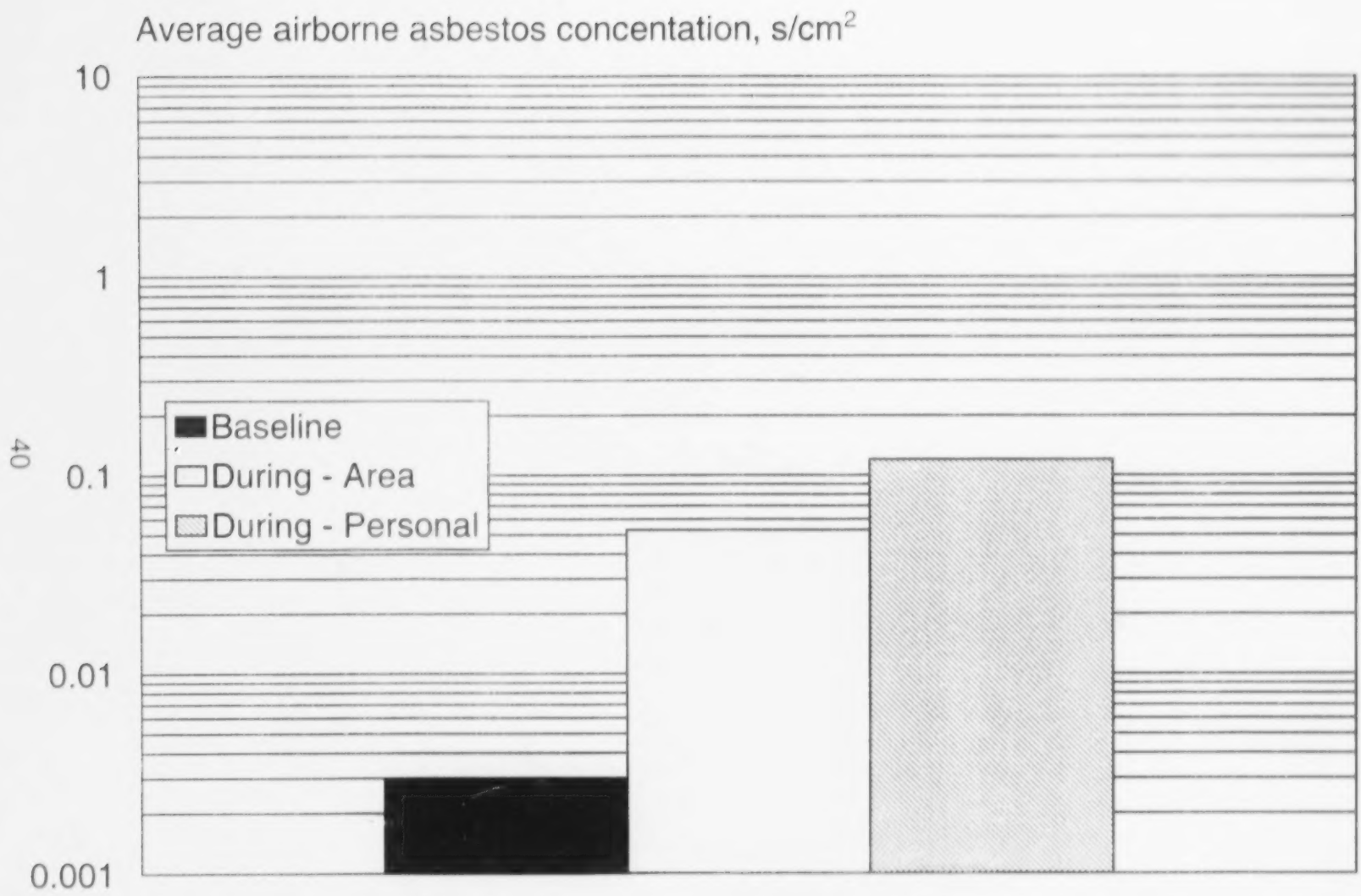

Figure 12. Average airborne asbestos concentrations before and during installation of fire alarm system at Site H.

The airborne asbestos levels measured during wet-stripping of the resilient floor tile were three orders of magnitude higher than the levels measured during the other O&M activities. These elevated levels during wet-stripping of resilient floor tile are consistent with those levels measured during other studies involving the same floor care maintenance practice.[7,8] Additionally, a study previously conducted on the spray-buffing of resilient floor tile demonstrated that this common maintenance procedure increased airborne asbestos concentrations at the majority of the study sites.[9]

In general, personal breathing zone concentrations tended to be slightly higher than area concentrations during the activities. This difference, however, was statistically significant during only one activity. The higher concentrations of asbestos measured by the personal breathing zone samples than the concentrations measured by the fixed-station area samples at Site F_2 are most likely attributable to differences in the proximity of the sampling cassettes to the source of the asbestos release, i.e., the O&M activity.

Asbestos Structure Size and Morphology Distributions

Table 9 summarizes the asbestos structure type and morphology distributions for samples collected before and during each O&M activity. All of the asbestos structures observed were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (63.0 percent) and, to a lesser extent, bundles (19.5 percent), matrices.

TABLE 9. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY BEFORE AND DURING O&M ACTIVITIES

Sampling Type	No. of Structures	Type of asbestos		Structure morphology			
		Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Site A - Wet-Stripping of Resilient Floor Tile							
Baseline	0	0	0	0	0	0	0
During - Area	645	100	0	70.9	16.9	2.0	10.2
During - Personal	298	100	0	69.8	21.5	0.3	8.4
Site B - Vacuuming Interior of Boilers							
Baseline	3	100	0	66.7	0	33.3	0
During - Area	7	100	0	57.1	28.6	0	14.3
During - Personal	0	0	0	0	0	0	0
Site C - Space Modification							
Baseline*	-	-	-	-	-	-	-
During - Area	46	100	0	15.2	10.9	2.2	71.7
Site D - Vacuuming Air Handling Unit							
Baseline	1	100	0	0	0	0	100
During - Area	2	100	0	50.0	0	0	50.0
During - Personal	2	100	0	50.0	0	0	50.0

(continued)

TABLE 9 (continued)

Sampling Type	No. of Structures	Type of asbestos		Structure morphology			
		Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Site F_1 - Changing Filters & Vacuuming Air Handling Units							
Baseline	4	100	0	25.0	25.0	0	50.0
During - Area	11	100	0	18.2	18.2	0	63.6
During - Personal	16	100	0	43.8	6.3	0	50.0
Site F_2 - Installation of Smoke Detector Wiring							
Baseline	1	100	0	100	0	0	0
During - Area	0	0	0	0	0	0	0
During - Personal	3	100	0	33.3	0	0	66.7
Site G_1 - Ceiling Tile Removal\Replacement							
Baseline	14	100	0	35.7	7.1	0	57.1
During - Area	5	100	0	40.0	0	20.0	20.0
During - Personal	3	100	0	33.3	0	0	66.7
Site G_2 - Installation of Flexible Conduit Above Suspended Ceiling							
Baseline	6	100	0	0	16.7	0	83.3
During - Area	12	100	0	16.7	16.7	8.3	58.3
During - Personal	6	100	0	16.7	16.7	0	66.7

(continued)

TABLE 9 (continued)

Sampling Type	No. of Structures	Type of asbestos		Structure morphology			
		Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Site H - Installation of Fire Alarm System							
Baseline	2	100	0	100	0	0	0
During - Area	68	100	0	48.5	25.0	2.9	23.5
During - Personal	174	100	0	57.5	31.0	0.6	10.9

* The renovation project started before the baseline fixed-station area air samples could be collected at this site.

(15.8 percent), and clusters (1.7 percent). The highest percentage of fibers was noted during wet-stripping of resilient floor tile (70.9 percent).

Table 10 presents the cumulative size distribution for the asbestos structures observed on samples collected before and during each O&M activity. Approximately 94 percent of the asbestos structures observed were less than or equal to 5 µm in length; approximately 45 percent were less than 1 µm in length.

PCM Air Monitoring Results

Table 11 presents the individual total fiber concentrations, along with the 8-hour TWA concentrations for the personal breathing zone samples collected during each O&M activity. The 8-hour TWA concentrations were calculated by assuming zero exposure beyond that which was measured during the activity. That is, the 8-hour TWA concentration was calculated by multiplying the sample duration (minutes) by the measured concentration (f/cm^3) and dividing the result by 480 minutes. None of the calculated 8-hour TWA concentrations exceeded the OSHA PEL of 0.1 f/cm^3, 8-hour TWA.

TABLE 10. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED BEFORE AND DURING O&M ACTIVITIES

Sampling type	No. of structures	Structure length, µm					
		≤ 1 µm	≤ 2 µm	≤ 3 µm	≤ 4 µm	≤ 5 µm	≤ 10 µm
Site A - Wet-Stripping of Resilient Floor Tile							
Baseline	0	0	0	0	0	0	0
During - Area	645	47.1	74.7	85.1	91.3	93.6	100
During - Personal	298	50.0	82.2	87.2	93.6	96.0	99.0
Site B - Vacuuming Interior of Boilers							
Baseline	3	66.7	66.7	66.7	66.7	100	100
During - Area	7	28.6	57.1	71.4	85.7	85.7	100
During - Personal	0	0	0	0	0	0	0
Site C - Space Modification							
Baseline							
During - Area	46	30.4	56.5	76.1	87.0	91.3	93.5
Site D - Vacuuming Air Handling Unit							
Baseline	1	100	100	100	100	100	100
During - Area	2	50	100	100	100	100	100
During - Personal	2	50	100	100	100	100	100

(continued)

TABLE 10 (continued)

Sampling type	No. of structures	Structure length, µm					
		≤ 1 µm	≤ 2 µm	≤ 3 µm	≤ 4 µm	≤ 5 µm	≤ 10 µm
Site F_1 - Changing Filters & Vacuuming Air Handling Unit							
Baseline	4	25.0	25.0	50.0	50.0	75.0	100
During - Area	11	18.2	81.8	90.9	90.9	90.9	90.9
During - Personal	16	6.3	56.3	81.3	81.3	93.8	100
Site F_2 - Installation of Smoke Detector Wiring							
Baseline	1	100	100	100	100	100	100
During - Area	0	0	0	0	0	0	0
During - Personal	3	33.3	66.7	66.7	66.7	66.7	66.7
Site G_1 - Ceiling Tile Removal/Replacement							
Baseline	14	64.3	92.9	100	100	100	100
During - Area	5	60.0	100	100	100	100	100
During - Personal	3	33.3	100	100	100	100	100
Site G_2 - Installation of Flexible Conduit Above Suspended Ceiling							
Baseline	6	16.7	66.7	83.3	83.3	83.3	100
During - Area	12	66.7	83.3	100	100	100	100
During - Personal	6	66.7	100	100	100	100	100

(continued)

TABLE 10 (continued)

Sampling type	No. of structures	Structure length, µm					
		≤ 1 µm	≤ 2 µm	≤ 3 µm	≤ 4 µm	≤ 5 µm	≤ 10 µm
Site H - Installation of Fire Alarm System							
Baseline	2	0	50.0	100	100	100	100
During - Area	68	32.4	77.9	88.2	92.6	94.1	100
During - Personal	174	35.6	75.3	87.4	93.1	96.0	97.1

TABLE 11. 8-HOUR TWA TOTAL FIBER CONCENTRATIONS (AS DETERMINED BY PCM) DURING O&M ACTIVITIES

Site	Activity	Sample Number	Sample Period, min	Total fiber concentration, f/cm³	
				Measured	8-hr TWA
A	Wet-Stripping of Resilient Floor Tile	A-01-D2-P-01	143	0.007	0.003
B	Vacuuming Interior of Boilers	B-01-D2-P-01	28	0.037	0.002
B	Vacuuming Interior of Boilers	B-01-D2-P-02	13	0.037	0.001
B	Vacuuming Interior of Boilers	B-01-D2-P-03	12	0.045	0.001
D	Vacuuming Air Handling Unit	D-01-D2-P-01	129	0.015	0.004
F_1	Changing Filters & Vacuuming Air Handling Units	F-01-D2-P-01	87	0.021	0.004
F_2	Installation of Smoke Detector Wiring	F-02-D2-P-03	60	0.033	0.004
G_1	Ceiling Tile Removal\Replacement	G-01-D2-P-01	72	0.026	0.004
G_2	Installation of Flexible Conduit Above Suspended Ceiling	G-02-D2-P-01	61	0.039	0.005
H	Installation of Fire Alarm System	H-01-D2-P-01	17	0.011	0.0004
				OSHA PEL	**0.1 f/cm³**

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APPENDIX A

NJDOH-EHS SITE EVALUATION/ASSESSMENT DOCUMENTATION FORM

NJDOH/EPA SITE EVALUATION/ASSESSMENT DOCUMENTATION FORM
Implementation of O&M Programs in NJ Schools

I. GENERAL INFORMATION

A. Building Data

1. Location Number: _____ Case Number: _____

2. Facility/Location: _____

   Building: _____ Building ID No: _____

3. Building Information

   Address: _____

   City: _____ State: _____ Zip: _____

   County: _____ County Code: _____

   Contact 1: _____ Title 1: _____

   Phone 1: _____

   Contact 2: _____ Title 2: _____

   Phone 2: _____

4. Asbestos Program Manager ( ) / Designated Person ( )

   Name: _____ Affiliation: _____

   Address: _____

   City: _____ State: _____ Zip: _____

   Phone: _____

5. Building Owner

   Name: _____

   Address: _____

   City: _____ State: _____ Zip: _____

   County: _____ County Code: _____

   Contact 1: _____ Title 1: _____

   Phone 1: _____

   Contact 2: _____ Title 2: _____

   Phone 2: _____

A. Building Data (continued)

6. Management Planner (MP)/Inspector

Original MP-Firm: _____ Date: _____

3-Year Reinspection-Firm: _____ Date: _____

Current Consultant-Firm: _____ Date: _____

7. Comments: _____

_____

_____

_____

8. Hours of Normal Building Occupancy: _____

9. Directions: _____

_____

_____

_____

B. Documentation Data

	Part 1	Part 2	Part 3
Date(s) Performed:			
Performed By: Building:	NA		
NJDOH/EPA:			
Form Completed By:			

Note Part 1 - Document and assess school's O&M program and other related components in the Asbestos Management Plan (NJDOH In-house)

Part 2 - Document and assess school's compliance with their O&M program during previously conducted O&M activities (on-site)

Part 3 - Observe and document the conduct of selected O&M activities covered under their O&M program (on-site)

II. BUILDING DESCRIPTION INFORMATION

1. Building Use(s): _____

2. Year Constructed: _____ Date(s) of Addition/Major Renovations: _____

3. Occupancy - Limit: _____ Normal Use: _____ Special Use: _____

4. Total Square Feet: _____ No. of Floors: _____ No. of Rooms: _____

5. Comments: _____

_____

_____

_____

_____

III. SITE INFORMATION

	Area A	Area B
1. Location(s) of Building:		
2. Use of Area(s):		
A. In-house Review - O&M /M.P.		
1. Abatement (Y/N):		
a. Type of ACM[1]:		
b. Approx. Amt. (s.f./l.f.):		
c. Location of ACM (pipes, walls, etc.):		
d. Abatement Type[2]:		
e. Date(s) for Completion:		
2. ACM in Area(s)		
a. Type of ACM[1]:		
b. Approx. Amt. (s.f./l.f.):		
c. Location of ACM (pipes, walls, etc.):		
d. Condition of ACM[3]:		
3. Comments:		

	Area A	Area B
B. On-Site Eval./Assess.		
1. Previous Abatement (Y/N)		
a. Type of ACM[1]		
b. Approx. Amt. (s.f./l.f.)		
c. Location of ACM (pipes, walls, etc.)		
d. Abatement Type[2]		
e. Date(s) Completed		
f. NJDOH Visual Inspection (Y/N)		
2. ACM in Area(s)		
a. Type of ACM[1]		
b. Approx. Amt. (s.f./l.f.)		
c. Location of ACM (pipes, walls, etc.)		
d. Condition of ACM[3]		
3. Comments		

IV. SITE O&M ACTIVITY INFORMATION

	Area A	Area B
1. Location(s) in Building		
2. Use of Area(s)		
A. Past O&M Activities		
1. Activity[4]		
2. Activity--		
a. On ACM (O)		
b. In Vicinity of ACM (V)		
3. Location(s) in Area		
4. Date(s) Performed		

	Area A	Area B
5. Performed By--		
a. Employee (E):		
b. Contractor (C):		
Name:		
Contact:		
Phone:		
B. Current O&M Activities		
1. Activity[4]:		
2. Activity--		
a. On ACM (O):		
b. In Vicinity of ACM (V):		
3. Date(s) - Start:		
Finish:		
4. Performed By--		
a. Employee(s):		
b. Contractor(s):		
Name:		
Contact:		
Phone:		
Employee:		
5. Time of Activity		
a. Day (D)/ Evening (E):		
b. Time(s):		
6. Length of Activity Per Day (hrs):		
C. Miscellaneous Notes:		

V. Asbestos Operations & Maintenance Program

Program Elements	Part 1 School's O&M / Management Plan (In-house Review)			Part 2 School's Compliance with Plan (On-site)			Part 3 Document O&M Activity (On-site)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
A. Administration/Awareness									
1. Designated Person (DP) / Asbestos Program Manager (APM)									
a. Is a DP or APM listed and actively employed?							-	-	X
b. Has the DP/APM received training?							-	-	X
c. Is the plan referenced by the DP/APM before any O&M work is performed?							-	-	X
2. Is the Plan available at the school for review and access? **(V)**									
3. Is the Plan updated periodically to reflect O&M activities or abatements? **(V)**							-	-	X
4. Is the Plan referenced by workers before performing an O&M activity?									
5. Do workers know the locations and availability of the Plan?									
6. Has an O&M Program been implemented?							-	-	X
7. Is the O&M Program followed?									
8. Are O&M staff and building occupants aware of who is the DP/APM? **(V)**	-	-	X						
9. Are response actions carried out and documented within the time frame outlined in the MP?	-	-	X				-	-	X
B. Notification									
1. Has written notification of the availability of the MP been provided to affected parties on a yearly basis?							-	-	X
2. Is written notification provided to outside contractors performing work at the school? **(V)**									
3. Are warning labels posted in routine maintenance areas? **(V)**									
C. Surveillance									
1. Have 6-month periodic surveillances been conducted?							-	-	X

Program Elements	Part 1 School's O&M / Management Plan (In-house Review)			Part 2 School's Compliance with Plan (On-site)			Part 3 Document O&M Activity (On-site)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
2 Has the MP been updated with the 6-month surveillance information? **(V)**								-	X
3 Have 3-year reinspections been conducted? **(V)**								-	X
4 Has the information from the 3-yr reinspection been incorporated into the MP? **(V)**								-	X
5 Does the MP identify or assume ACM to be present in the vicinity of the selected activity?								-	X
6 For reinspections, did the reinspector visually reinspect and reassess the condition of all friable known or assumed ACM?	-	-	X					-	X
D. WORK CONTROLS/PERMIT SYSTEM									
1 Does the O&M Program contain a work control/permit system? **(V)**									
2 Is the work control/permit system documented in the O&M Program?									
3 Does the DP/APM physically inspect the area in which work is to be performed to ensure records reflect actual conditions?									
4 Is the work performed by outside contractors reviewed by the DP/APM to determine the presence of ACM where the work is to be performed?									
5 Is the person requesting the work required to submit a Work Request to the DP/APM? **(V)**									
6 Upon receiving the Work Request, does the DP/APM do the following									
a Determine whether ACM is present in the area where work will occur?									
b If ACM is present and will likely be disturbed, does the DP/APM visit the site to determine what work practices should be initiated to minimize the release of asbestos fibers during the maintenance activity?									
c If the task is not covered by previously approved standard work practices, does the DP/APM make sure that the appropriate work practices and protective measures are used for the job?									
d Does the DP/APM inspect the site after work is performed?									

(V) On-Site Verification denotes that responses to the questions followed by a "V" are to be verified on-site by the interviewer.

Program Elements	Part 1 School's O&M / Management Plan (In-house Review)			Part 2 School's Compliance with Plan (On-site)			Part 3 Document O&M Activity (On-site)		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
E. WORK PRACTICES									
1 Have specific work practices been developed and utilized for activities (See Code 4)? **(V)**									
2 Do specific work practices contain step-by-step procedures for conducting the activity?									
3 Has cleaning been performed prior to all response actions conducted?							-	-	X
4 Were the specific procedures in the O&M Program followed?	-	-	X						
5 Have specific work practices been developed for fiber release episodes?							-	-	X
F. RECORDKEEPING									
1 Are records maintained in a centralized location at the school? **(V)**									
2 Was each custodial/maintenance person required to receive training, trained? **(V)**									
3 Is each periodic surveillance documented? **(V)**									
4 Is each O&M activity documented?									
G. WORKER PROTECTION									
1 Is a written worker protection program outlined as part of the O&M Program? **(V)**									
2 For the activities monitored (Code 4), were the proper worker protection items used?									
H. TRAINING									
1 Was awareness training provided for custodians involved in cleaning and simple maintenance tasks where ACM may accidently be disturbed? **(V)**									
2 Was special O&M training provided for maintenance workers involved in general maintenance and incidental ACM repair tasks? **(V)**									

(V) On-Site Verification denotes that responses to the questions followed by a "V" are to be verified on-site by the interviewer.

CODES

[1] ACM Types

PB = Preformed block (thermal system insulation)

AC = Air cell (thermal system insulation)

LP = Layered paper (thermal system insulation)

CEM = cementitious insulation (thermal system insulation)

BD = Asbestos board (thermal system insulation)

AP = Acoustical plaster (surfacing material)

FP = Fireproofing (surfacing material)

CT = Ceiling Tile (miscellaneous material)

FT = Floor tile (miscellaneous material)

TR = Transite (miscellaneous material)

PAP = Paper-like material (miscellaneous material)

Other (describe)

[2] Abatement Type

REM = Removal

REP = Repair

ENCP = Encapsulation

ENCL = Enclosure

[3] Condition of ACM

P = Poor

F = Fair

G = Good

E = Excellent

[4] Activities

I. OPERATIONS (CUSTODIAL/SERVICE) ACTIVITIES

1. Dry-dusting/sweeping/mopping of asbestos-containing floor tile.
2. Spray-buffing asbestos-containing floor tile.
3. Stripping/refinishing asbestos-containing floor tile.
4. Dry burnishing asbestos-containing floor tile.
5. Carpet vacuuming.
6. Carpet cleaning (wet-vacuuming).
7. Dry-dusting/sweeping/mopping of surfaces and floors.
8. Maintenance/installation/cleaning of draperies, shades, or other window treatments.
9. Other.

II. MAINTENANCE ACTIVITIES

A. HVAC

1. Repair/maintenance of mechanical equipment (e.g., boilers, air-handling units, heat exchangers, tanks) in utility spaces.
2. Adjustment/repair/maintenance of HVAC systems (e.g., ductwork, variable air volume boxes, mixing boxes, dampers, pneumatic controls).
3. Air filter replacement/cleaning of grills, diffusers, or registers.
4. Repair/replacement of pipe or duct insulation.
5. Valve or gasket replacement.
6. Other.

B. PLUMBING

1. Installation/removal/modification of piping or equipment (e.g., domestic hot and cold water lines, roof drains, storage tanks, water pumps).
2. Repair/replacement of plumbing system components.
3. Repair/replacement of pipe insulation.
4. Other.

C. ELECTRICAL/COMMUNICATIONS

1. Connections and/or extensions for electrical systems (e.g., installing conduit, electrical boxes).
2. Repair/replacement of lighting/electrical fixtures.
3. Installation/modification of telecommunications or computer network (e.g., pulling cable).
4. Other.

D. FIRE PROTECTION

1. Installation/repair of sprinkler system components.
2. Installation of smoke or heat detection equipment.
3. Testing/cleaning/repair/replacement of smoke or heat detection equipment.
4. Other.

E. OTHER BUILDING SYSTEMS

1. Repair/replacement of asbestos-containing floor tile.
2. Other.

III. RENOVATION ACTIVITIES

1. Carpet removal.
2. Ceiling tile installation/repair/replacement.
3. General space modification-repair/replacement of walls, ceilings, and plaster (e.g., installing, demolishing partitions).
4. Repair/replacement of roofing materials.
5. Other.

APPENDIX B

INDIVIDUAL ESTIMATES OF AIRBORNE ASBESTOS CONCENTRATIONS MEASURED BEFORE AND DURING OPERATION AND MAINTENANCE ACTIVITIES

APPENDIX B. INDIVIDUAL ESTIMATES OF AIRBORNE ASBESTOS CONCENTRATIONS MEASURED BEFORE AND DURING OPERATION AND MAINTENANCE ACTIVITIES

Site	Date Sampled	Sample Number	Sample Type	Air Volume, L	Concentration s/cm³	s/mm²
A	08/01/94	A-01-B-01	Baseline	1350	<0.004	<13.9
A	08/01/94	A-01-B-02	Baseline	1407	<0.004	<13.9
A	08/01/94	A-01-B-03	Baseline	1365	<0.004	<13.9
A	08/01/94	A-01-B-04	Baseline	1375	<0.004	<13.9
A	08/01/94	A-01-B-05	Baseline	1385	<0.004	<13.9
A	08/01/94	A-01-B-OB1	Open Field Blank	0		<13.9
A	08/01/94	A-01-B-CB1	Closed Field Blank	0		<13.9
A	08/02/94	A-01-D1-01	During - Area	1321	3.562	12222
A	08/02/94	A-01-D1-02	During - Area	1385	3.768	13556
A	08/02/94	A-01-D1-03	During - Area	1439	3.300	12333
A	08/02/94	A-01-D1-04	During - Area	1403	4.269	15556
A	08/02/94	A-01-D1-05	During - Area	1431	4.843	18000
A	08/02/94	A-01-D1-P-01	During - Personal	1348	3.031	10611
A	08/02/94	A-01-D1-P-02	During - Personal	1279	3.579	11889
A	08/02/94	A-01-D1-P-02R[a]	During - Personal	1279	3.846	12778
A	08/02/94	A-01-D1-OB1	Open Field Blank	0		<11.1
A	08/02/94	A-01-D1-CB1	Closed Field Blank	0		<13.9
A	08/15/94	HUNJ01	Followup	1203	0.053	166.7
A	08/15/94	HUNJ02	Followup	1131	0.059	172.8
A	08/15/94	HUNJ03	Followup	1203	0.071	222.2
A	08/15/94	HUNJ04	Followup	1131	0.059	172.8
A	08/15/94	HUNJ05	Followup	1218	0.044	138.9
A	08/15/94	HUNJ06	Closed Field Blank	0		<13.9
A	08/15/94	HUNJ07	Open Field Blank	0		<13.9
A	08/15/94	HUNJ08	Open Field Blank	0		<13.9
A	08/15/94	HUNJ09	Followup	1160	0.229	691.4
A	08/25/94	RHUNJ01	Followup	1247	<0.004	<13.9
A	08/25/94	RHUNJ02	Followup	1164	<0.004	<12.3
A	08/25/94	RHUNJ03	Followup	1140	<0.004	<12.3
A	08/25/94	RHUNJ04	Followup	1176	<0.004	<12.3
A	08/25/94	RHUNJ05	Followup	1247	<0.004	<13.9
A	08/25/94	RHUNJ09	Followup	1140	<0.005	<13.9
A	08/25/94	RHUNJ06	Open Field Blank	0		<13.9
A	08/25/94	RHUNJ07	Closed Field Blank	0		<13.9
A	08/25/94	RHUNJ08	Closed Field Blank	0		<13.9
B	08/02/94	B-01-B-01	Baseline	1224	<0.004	<13.9
B	08/02/94	B-01-B-02	Baseline	1143	<0.004	<12.3
B	08/02/94	B-01-B-03	Baseline	1160	<0.004	<12.3
B	08/02/94	B-01-B-04	Baseline	1144	0.009	27.8
B	08/02/94	B-01-B-05	Baseline	1218	0.004	13.9
B	08/02/94	B-01-B-OB1	Open Field Blank	0		<11.1
B	08/02/94	B-01-B-CB1	Closed Field Blank	0		<11.1
B	08/03/94	B-01-D1-01	During - Area	420	0.010	11.1
B	08/03/94	B-01-D1-02	During - Area	358	<0.005	<4.6
B	08/03/94	B-01-D1-03	During - Area	368	0.005	4.6
B	08/03/94	B-01-D1-04	During - Area	363	<0.005	<4.6

(continued)

APPENDIX B (continued)

Site	Date Sampled	Sample Number	Sample Type	Air Volume, L	Concentration s/cm³	Concentration s/mm²
B	08/03/94	B-01-D1-05	During - Area	343	0.021	18.5
B	08/03/94	B-01-D1-P-02	During - Personal	284	<0.004	<3.1
B	08/03/94	B-01-D1-OB1	Open Field Blank	0		<13.9
B	08/03/94	B-01-D1-CB1	Closed Field Blank	0		<13.9
C	05/15/92[c]	C-01-B-01	Baseline	-	<0.003	-
C	05/15/92[c]	C-01-B-02	Baseline	-	0.008	-
C	05/15/92[c]	C-01-B-03	Baseline	-	<0.003	-
C	05/15/92[c]	C-01-B-04	Baseline	-	0.006	-
C	05/15/92[c]	C-01-B-05	Baseline	-	0.003	-
C	08/04/94	C-01-D1-01	During - Area	934	0.014	33.3
C	08/04/94	C-01-D1-02	During - Area	932	0.041	100.0
C	08/04/94	C-01-D1-03	During - Area	911	0.038	90.9
C	08/04/94	C-01-D1-04	During - Area	911	0.017	40.4
C	08/04/94	C-01-D1-05	During - Area	945	0.050	122.2
C	08/04/94	C-01-D1-06	During - Area	896	0.009	20.2
C	08/04/94	C-01-D1-07	During - Area	938	<0.004	<10.1
C	08/04/94	C-01-D1-08	During - Area	923	0.034	80.8
C	08/04/94	C-01-D1-OB1	Open Field Blank	0		<11.1
C	08/04/94	C-01-D1-CB1	Closed Field Blank	0		<11.1
D	08/04/94	D-01-B-01	Baseline	1226	0.004	13.9
D	08/04/94	D-01-B-02	Baseline	1241	<0.004	<13.9
D	08/04/94	D-01-B-03	Baseline	1314	<0.004	<13.9
D	08/04/94	D-01-B-06	Baseline	1213	<0.004	<13.9
D	08/04/94	D-01-B-07	Baseline	1213	<0.004	<13.9
D	08/04/94	D-01-B-OB1	Open Field Blank	0		<13.9
D	08/04/94	D-01-B-CB1	Closed Field Blank	0		<13.9
D	08/05/94	D-01-D1-01	During - Area	1267	<0.004	<13.9
D	08/05/94	D-01-D1-01D[b]	During - Area	1267	<0.004	<13.9
D	08/05/94	D-01-D1-02	During - Area	1263	<0.004	<13.9
D	08/05/94	D-01-D1-03	During - Area	1184	0.004	12.3
D	08/05/94	D-01-D1-04	During - Area	1198	<0.004	<12.3
D	08/05/94	D-01-D1-05	During - Area	1232	0.004	13.9
D	08/05/94	D-01-D1-P-01	During - Personal	1222	0.004	13.9
D	08/05/94	D-01-D1-P-01R	During - Personal	1222	0.004	13.9
D	08/05/94	D-01-D1-P-02	During - Personal	750	0.004	7.9
D	08/05/94	D-01-D1-P-03	During - Personal	496	<0.004	<5.6
D	08/05/94	D-01-D1-OB1	Open Field Blank	0		<13.9
D	08/05/94	D-01-D1-OB2	Open Field Blank	0		<13.9
D	08/05/94	D-01-D1-CB1	Closed Field Blank	0		<13.9
E	08/05/94	E-01-B-01	Baseline	1330	<0.005	<15.9
E	08/05/94	E-01-B-02	Baseline	1311	<0.005	<15.9
E	08/05/94	E-01-B-03	Baseline	1269	0.005	15.9
E	08/05/94	E-01-B-04	Baseline	1218	<0.005	<15.9
E	08/05/94	E-01-B-05	Baseline	1293	<0.005	<15.9
E	08/05/94	E-01-B-05R	Baseline	1293	0.004	13.9
E	08/05/94	E-01-B-OB1	Open Field Blank	0		<13.9
E	08/05/94	E-01-B-CB1	Closed Field Blank	0		<13.9

(continued)

APPENDIX B (continued)

Site	Date Sampled	Sample Number	Sample Type	Air Volume, L	Concentration s/cm^3	s/mm^2
E	08/08/94	E-01-D1-01	During - Area	880		
E	08/08/94	E-01-D1-02	During - Area	809		
E	08/08/94	E-01-D1-03	During - Area	810		
E	08/08/94	E-01-D1-04	During - Area	781		
E	08/08/94	E-01-D1-05	During - Area	762		
E	08/08/94	E-01-D1-OB1	Open Field Blank	0		<13.9
E	08/08/94	E-01-D1-CB1	Closed Field Blank	0		<13.9
F	08/08/94	F-01-B-01	Baseline	1243	0.013	41.7
F	08/08/94	F-01-B-02	Baseline	1228	<0.004	<13.9
F	08/08/94	F-01-B-02R	Baseline	1228	<0.004	<13.9
F	08/08/94	F-01-B-03	Baseline	1253	0.004	13.9
F	08/08/94	F-01-B-04	Baseline	1276	<0.004	<13.9
F	08/08/94	F-01-B-05	Baseline	1236	<0.004	<13.9
F	08/08/94	F-01-B-OB1	Open Field Blank	0		<13.9
F	08/08/94	F-01-B-CB1	Closed Field Blank	0		<13.9
F	08/09/94	F-01-D1-01	During - Area	934	<0.005	<12.3
F	08/09/94	F-01-D1-02	During - Area	987	0.024	61.7
F	08/09/94	F-01-D1-03	During - Area	1033	0.018	49.4
F	08/09/94	F-01-D1-04	During - Area	1025	0.009	24.7
F	08/09/94	F-01-D1-05	During - Area	955	<0.005	<12.3
F	08/09/94	F-01-D1-P-01	During - Personal	829	0.046	98.8
F	08/09/94	F-01-D1-P-02	During - Personal	825	0.038	80.8
F	08/09/94	F-01-D1-OB1	Open Field Blank	0		<13.9
F	08/09/94	F-01-D1-CB1	Closed Field Blank	0		<13.9
F	08/09/94	F-02-B-01	Baseline	914	<0.004	<10.1
F	08/09/94	F-02-B-02	Baseline	919	<0.005	<11.1
F	08/09/94	F-02-B-03	Baseline	881	<0.004	<10.1
F	08/09/94	F-02-B-04	Baseline	908	<0.005	<11.1
F	08/09/94	F-02-B-04R	Baseline	908	<0.005	<11.1
F	08/09/94	F-02-B-05	Baseline	811	0.005	10.1
F	08/09/94	F-02-B-OB1	Open Field Blank	0		<13.9
F	08/09/94	F-02-B-CB1	Closed Field Blank	0		<13.9
F	08/09/94	F-02-D1-01	During - Area	740	<0.005	<9.3
F	08/09/94	F-02-D1-02	During - Area	758	<0.005	<9.3
F	08/09/94	F-02-D1-03	During - Area	699	<0.005	<8.5
F	08/09/94	F-02-D1-04	During - Area	697	<0.005	<8.5
F	08/09/94	F-02-D1-05	During - Area	716	<0.005	<8.5
F	08/09/94	F-02-D1-P-01	During - Personal	656	0.005	8.5
F	08/09/94	F-02-D1-P-02	During - Personal	664	0.010	17.1
F	08/09/94	F-02-D1-P-02D	During - Personal	664	0.005	8.5
F	08/09/94	F-02-D1-OB1	Open Field Blank	0		<13.9
F	08/09/94	F-02-D1-CB1	Closed Field Blank	0		<13.9
G	08/09/94	G-01-B-01	Baseline	1369	<0.004	<13.9
G	08/09/94	G-01-B-01R	Baseline	1369	0.004	13.9
G	08/09/94	G-01-B-02	Baseline	1194	0.004	12.3
G	08/09/94	G-01-B-03	Baseline	1336	0.008	27.8
G	08/09/94	G-01-B-04	Baseline	1410	0.009	31.7

(continued)

APPENDIX B (continued)

Site	Date Sampled	Sample Number	Sample Type		Air Volume, L	Concentration s/cm³	Concentration s/mm²
G1	08/09/94	G-01-B-05	Baseline	1420	0.039	142.9	
G1	08/09/94	G-01-B-CB1	Closed Field Blank	0	<13.9		
G1	08/09/94	G-01-B-OB1	Open Field Blank	0		<13.9	
G1	08/10/94	G-01-D1-01	During - Area	810	<0.004	<9.3	
G1	08/10/94	G-01-D1-02	During - Area	815	0.004	9.3	
G1	08/10/94	G-01-D1-03	During - Area	742	0.004	7.9	
G1	08/10/94	G-01-D1-04	During - Area	790	0.004	8.5	
G1	08/10/94	G-01-D1-05	During - Area	790	0.008	17.1	
G1	08/10/94	G-01-D1-P-01	During - Personal	635	0.004	6.9	
G1	08/10/94	G-01-D1-P-02	During - Personal	635	0.008	13.9	
G1	08/10/94	G-01-D1-OB1	Open Field Blank	0	<13.9		
G1	08/10/94	G-01-D1-CB1	Closed Field Blank	0	<13.9		
G2	08/11/94	G-02-D1-01	During - Area	739	0.008	15.9	
G2	08/11/94	G-02-D1-01D	During - Area	739	0.012	23.8	
G2	08/11/94	G-02-D1-02	During - Area	693	0.009	15.9	
G2	08/11/94	G-02-D1-03	During - Area	679	0.023	39.7	
G2	08/11/94	G-02-D1-04	During - Area	744	<0.004	<7.9	
G2	08/11/94	G-02-D1-05	During - Area	655	0.014	23.8	
G2	08/11/94	G-02-D1-P-01	During - Personal	552	<0.005	<6.5	
G2	08/11/94	G-02-D1-P-02	During - Personal	572	0.026	39.2	
G2	08/11/94	G-02-B-OB1	Open Field Blank	0		<13.9	
G2	08/11/94	G-02-D1-OB1	Open Field Blank	0		<13.9	
G2	08/11/94	G-02-B-CB1	Closed Field Blank	0		<13.9	
G2	08/11/94	G-02-D1-CB1	Closed Field Blank	0		<13.9	
G2	08/11/94	G-02-B-01	Baseline	1181	<0.004	<12.3	
G2	08/11/94	G-02-B-01R	Baseline	1181	<0.004	<12.3	
G2	08/11/94	G-02-B-02	Baseline	1200	0.013	41.7	
G2	08/11/94	G-02-B-03	Baseline	1129	0.013	37.0	
G2	08/11/94	G-02-B-04	Baseline	1150	<0.004	<12.3	
G2	08/11/94	G-02-B-05	Baseline	1252	<0.004	<13.9	
H	08/10/94	H-01-B-01	Baseline	1296	0.004	13.9	
H	08/10/94	H-01-B-02	Baseline	1203	0.004	13.9	
H	08/10/94	H-01-B-03	Baseline	1302	<0.004	<13.9	
H	08/10/94	H-01-B-04	Baseline	1281	<0.004	<13.9	
H	08/10/94	H-01-B-05	Baseline	1307	<0.004	<13.9	
H	08/10/94	H-01-B-05R	Baseline	1307	<0.004	<13.9	
H	08/10/94	H-01-B-OB1	Open Field Blank	0		<13.9	
H	08/10/94	H-01-B-CB1	Closed Field Blank	0		<13.9	
H	08/11/94	H-01-D1-01	During - Area	1107	0.047	135.8	
H	08/11/94	H-01-D1-02	During - Area	1122	0.076	222.2	
H	08/11/94	H-01-D1-03	During - Area	1181	0.056	172.8	
H	08/11/94	H-01-D1-04	During - Area	1123	0.030	86.4	
H	08/11/94	H-01-D1-05	During - Area	1171	0.073	222.2	
H	08/11/94	H-01-D1-P-01	During - Personal	867	0.064	144.8	
H	08/11/94	H-01-D1-P-02	During - Personal	764	0.226	448.9	
H	08/11/94	H-01-D1-CB1	Closed Field Blank	0		<13.9	
H	08/31/94	H-01-F1-01	Followup	1241	<0.004	<13.9	

(continued)

APPENDIX B (continued)

Site	Date Sampled	Sample Number	Sample Type	Air Volume, L	Concentration s/cm^3	s/mm^2
H	08/31/94	H-01-F1-02	Followup	1249	<0.004	<13.9
H	08/31/94	H-01-F1-03	Followup	1330	<0.004	<13.9
H	08/31/94	H-01-F1-04	Followup	1360	<0.004	<15.9
H	08/31/94	H-01-F1-04D	Followup	1360	<0.004	<15.9
H	08/31/94	H-01-F1-05	Followup	1280	<0.004	<13.9
H	08/31/94	H-01-F1-05R	Followup	1280	<0.004	<13.9
H	08/31/94	H-01-F1-OB1	Open Field Blank	0		<13.9

[a] Samples ending with 'R' represent a replicate laboratory analysis of that sample.

[b] Samples ending with 'D' represent a duplicate laboratory analysis of that sample.

[c] Historical data based on sampling conducted in this school by U.S. EPA in May 1992. It was not possible to obtain baseline data at this site in 1994.

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

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